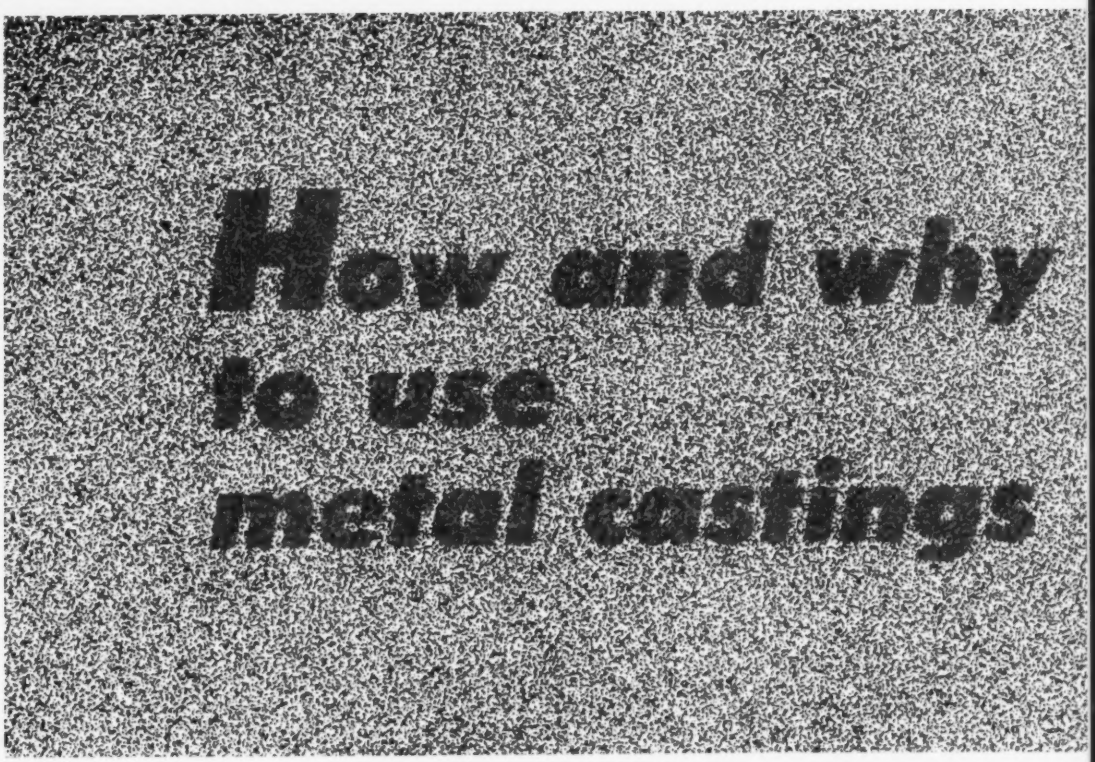
modern castings

AFS MARCH 1959

Presenting a modern castings FORUM for DESIGNERS and BUYERS



14 special articles
start on page 23

Dependable East Jordan fire hydrants call for dependable

HANNA PIG IRON

The Midwest Hydrant, developed by East Jordan Iron Works, is built to American Water Works Association specifications and is approved by Underwriters' Laboratories.

The lives and property of millions of people depend on the successful operation of fire protection equipment made by East Jordan Iron Works at East Jordan, Michigan. In business since 1883, East Jordan produces hydrants for the largest to the smallest municipalities in the Midwest.

Because of the importance of dependable fire protection equipment, hydrants and valves must be in "condition readiness" at all times. This requires an iron that will resist temperature extremes, oxidation and corrosive forces from contact with earthy materials. Only a metallurgically sound casting that will stand up under rigid pressure and toughness requirements can do the job. That's why the fine-grained, closely controlled structure and the uniform chemical analysis of Hanna Pig Iron make it ideal for such an application.

Hanna produces all regular grades of pig iron plus HANNATITE® and Hanna Silvery. All grades are available in 38-lb. pigs and the smaller HANNATEN® 12½-lb. ingots. For complete details about Hanna products, contact your Hanna representative.

THE HANNA FURNACE CORPORATION
Buffalo • Detroit • New York • Philadelphia
Merchant Pig Iron Division of
NATIONAL STEEL CORPORATION

Circle No. 701, Page 167-168

march, 1959
vol. 35, no. 3

modern castings

the technical magazine of the metalcasting industry

features

Introduction to Design Forum 23
How and Why to Use Gray Iron Castings 24
by R. C. Meloy
How and Why to Use Malleable Iron Castings 27
by Hans Heine
How and Why to Use Steel Castings 30
by C. W. Briggs and G. K. Dreher
How and Why to Use Alloy Castings 34
by E. A. Schoefer
How and Why to Use Nonferrous Castings 36
by Herbert F. Scobie
How and Why to Use Magnesium Castings 39
by Jerry Singleton
How and Why to Use Investment Castings 42
by R. R. Miller
How and Why to Use Die Castings 45
by David Laine
General Motors Describes CentraSteel 48
by W. B. Larson, C. F. Joseph, F. J. Webbere and R. F. Thomson

1959 Castings Congress Papers

Aid for the Design Engineer: Foundrymen! "Accentuate the Positive"
by Jules J. Henry 53
How Aircraft Designers Look at Light Metal Castings
by Albert R. Mead 61
Design Engineering as Related to Magnesium Castings
by George H. Found 67
Factors Influencing Soundness of Gray Iron Castings, A Review of Some Recent British Work
by I. C. H. Hughes, K. E. L. Nicholas, A. G. Fuller and T. J. Szajda 73
Bending Techniques for Evaluation of Cast Materials and Structures, A Preliminary Appraisal
by J. C. Graddy 90
Starch Content Effect on a Rammed Graphitic Mold Material for Casting Titanium
by H. W. Antes and R. E. Edelman 97
Ductility and Strength of High-Carbon Gray Irons
by E. M. Stein and H. O. McIntire 103
Ductile Iron As-Cast and Annealed Tensile Properties
by A. H. Rauch, J. B. Peck and E. M. McCullough 111

departments

Advertisers and Their Agencies 166
AFS News 117
Chapter Meetings 133
Classified Advertising 164
Dietrich's Corner by H. W. Dietrich 20
Editor's Report 5
For The Asking 142
Foundry Trade News 136
Future Meetings & Exhibits . 2
How's Business 21
Let's Get Personal 138
Obituaries 140
Pouring Off the Heat 15
Products & Processes 6
Reader Service Card 167

featurette

Plant-Made Air Replacement System Ups Foundry Morale 166

future meetings and exhibits

MARCH

9-10 . . Steel Founders' Society of America, *Annual Meeting*. Drake Hotel, Chicago.

11-12 . . Instrument Society of America, *Iron and Steel Conference*. Pick-Roosevelt Hotel, Pittsburgh, Pa.

13-14 . . AFS *California Regional Foundry Conference*. Huntington-Sheraton Hotel, Pasadena, Calif.

16-20 . . American Society for Metals, *11th Western Metal Exposition & Congress*. Pan-Pacific Auditorium and Ambassador Hotel, Los Angeles.

17-19 . . National Association of Corrosion Engineers, *Annual Conference & Show*. Sherman Hotel, Chicago.

17-19 . . Investment Casting Institute, *Technical Session*. Surf Rider Inn, Santa Monica, Calif.

18-19 . . Foundry Educational Foundation, *Annual College-Industry Conference*. Hotel Statler-Hilton, Cleveland.

19-20 . . AFS *Texas Regional Foundry Conference*. Menger Hotel, San Antonio, Texas.

APRIL

5-10 . . American Chemical Society, *Spring Meeting*. Boston.

5-10 . . *Nuclear Congress and Atom-fair*. Public Auditorium, Cleveland.

6-8 . . American Institute of Mining, Metallurgical & Petroleum Engineers, *National Open Hearth Steel Conference*. Hotel Jefferson, St. Louis.

6-10 . . American Welding Society, *Annual Meeting and Welding Exposition*. Hotel Sherman, Chicago.

8-9 . . Malleable Founders' Society, *Market Development Conference*. Hotel Cleveland, Cleveland.

13 . . Cast Bronze Bearing Institute, *Spring Meeting*. Sherman Hotel, Chicago.

13-17 . . AFS *Engineered Castings Show and 63d Annual Castings Congress*. Hotels Sherman and Morrison, Chicago.

16 . . National Castings Council, *Annual Meeting*. Sherman Hotel, Chicago.

16-17 . . Magnesium Association, *Casting Section Meeting*. Congress Hotel, Chicago.

18-22 . . American Society of Tool Engineers, *Annual Meeting*. Schroeder Hotel, Milwaukee.

30–May 11 . . 32d *International Fair*. Brussels, Belgium.

MAY

13-15 . . National Industrial Sand Association, *Annual Meeting*. The Homestead, Hot Springs, Va.

25-26 . . Malleable Founders' Society, *Annual Meeting*. The Homestead, Hot Springs, Va.

27-28 . . American Iron and Steel Institute, *Annual Meeting*. Waldorf-Astoria Hotel, New York.

JUNE

9-12 . . Material Handling Institute, *Exposition*. Public Auditorium, Cleveland.

11-12 . . AFS *Chapter Officers Conference*. AFS Headquarters, Des Plaines, Ill. and Sherman Hotel, Chicago.

18-20 . . AFS *Foundry Instructors Seminar*. University of Illinois, Urbana, Ill.

21-26 . . American Society for Testing Materials, *Annual Meeting*. Chalfonte-Haddon Hall, Atlantic City, N.J.

25-27 . . AFS *Penn State Foundry Conference*. Pennsylvania State University, University Park, Pa.

SEPTEMBER

24-26 . . AFS *Missouri Valley Regional Foundry Conference*. Missouri School of Mines, Rolla, Mo.

28-Oct. 1 . . Association of Iron and Steel Engineers, *Annual Convention*. Sherman Hotel, Chicago.

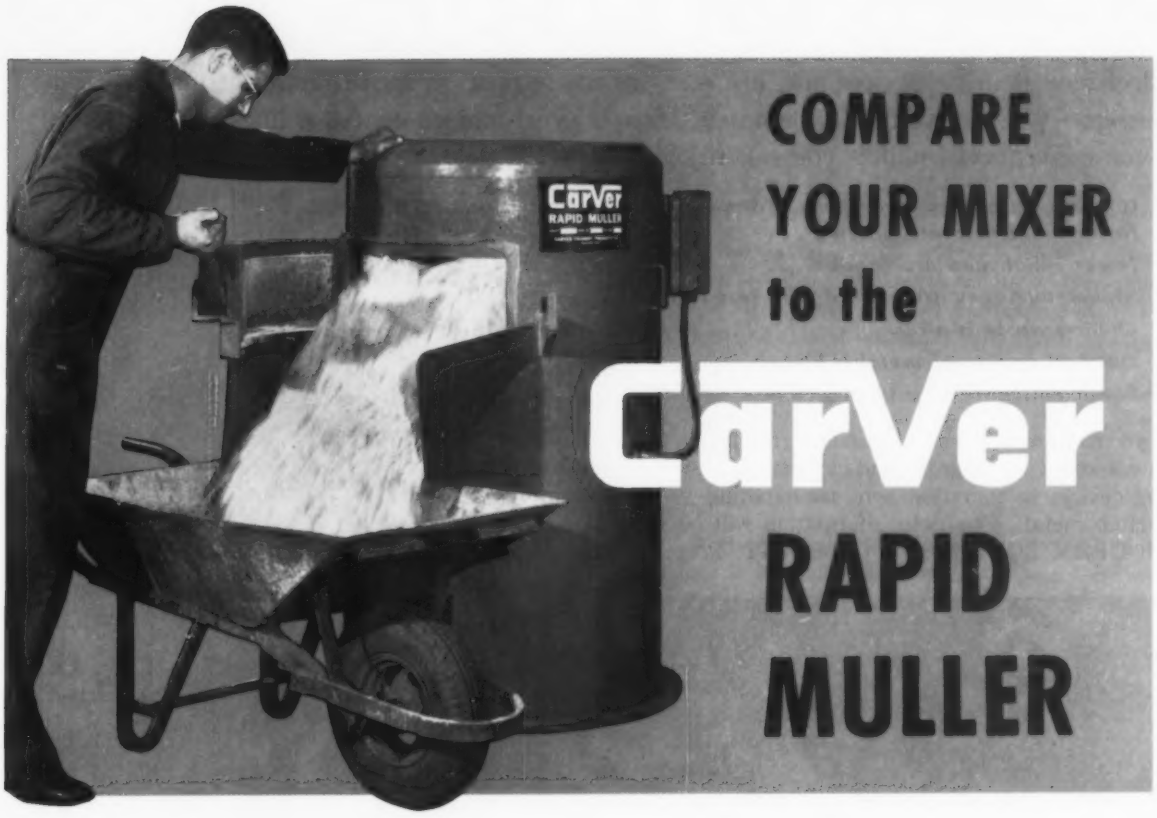
OCTOBER

16-17 . . AFS *New England Regional Foundry Conference*. Massachusetts Institute of Technology, Cambridge, Mass.

22-23 . . AFS *Ohio Regional Foundry Conference*. Battelle Memorial Institute, Columbus, Ohio.

MODERN CASTINGS is indexed by Engineering Index, Inc., 29 West 39th St., New York 18, N. Y. and microfilmed by University Microfilms, 313 N. First St., Ann Arbor, Mich.
The American Foundrymen's Society is not responsible for statements or opinions advanced by authors of papers or articles printed in its publication.
Published monthly by the American Foundrymen's Society, Inc., Golf & Wolf Roads, Des Plaines, Ill. Subscription price in the U.S., $5.00 per year; elsewhere, $7.50. Single copies 50c. April, May and June issues $1.00. Entered as second-class mail at Pontiac, Illinois. Additional entry at Des Plaines, Ill.

AUDITED PAID CIRCULATION ABC



COMPARE YOUR MIXER to the CarVer RAPID MULLER

COMPARE SPEED

With the Carver Rapid Muller, you get a batch *every 75 seconds!*

COMPARE PERFORMANCE

Absolutely NO lumps or wet spots. Each grain of sand receives an equal coating of binder.

COMPARE CONVENIENCE

Patented self-cleaning mixing arm eliminates back-breaking cleaning chores.

COMPARE VERSATILITY

Carver Rapid Muller does a first-class job with molding sand, oil sand, resin sand, or CO_2 sand . . . any kind of binder.

COMPARE COST

Your initial investment is three times lower than most mixers . . . yet you save as much as 30% in binder. Extreme simplicity of design, with only one moving part, keeps maintenance costs at a bare minimum.

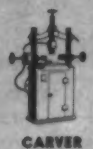
THESE ARE THE FACTS

Now you know why the Carver Rapid Muller is THE MOST FANTASTIC BUY IN THE BUSINESS — and why over 4,000 Carver Rapid Mullers are now in use. If you want an "on-the-spot" comparison — mail coupon today and SEE FOR YOURSELF why nothing — absolutely nothing — compares with Carver Rapid Muller.

WRITE OR CALL TODAY FOR COMPLETE DETAILS

Only CarVer Has Everything For the CO_2 Process!

CARVER V & S Core Shooters



CARVER Automatic Gassing Apparatus

KRAUSS Taper Slot Core Vents

STEINEX available only from **CARVER**

MAIL TODAY

CARVER FOUNDRY PRODUCTS CO.
Muscatine, Iowa

We're interested! Rush information on Carver Rapid Muller.

NAME _____ TITLE _____

FOUNDRY _____

CITY _____ STATE _____

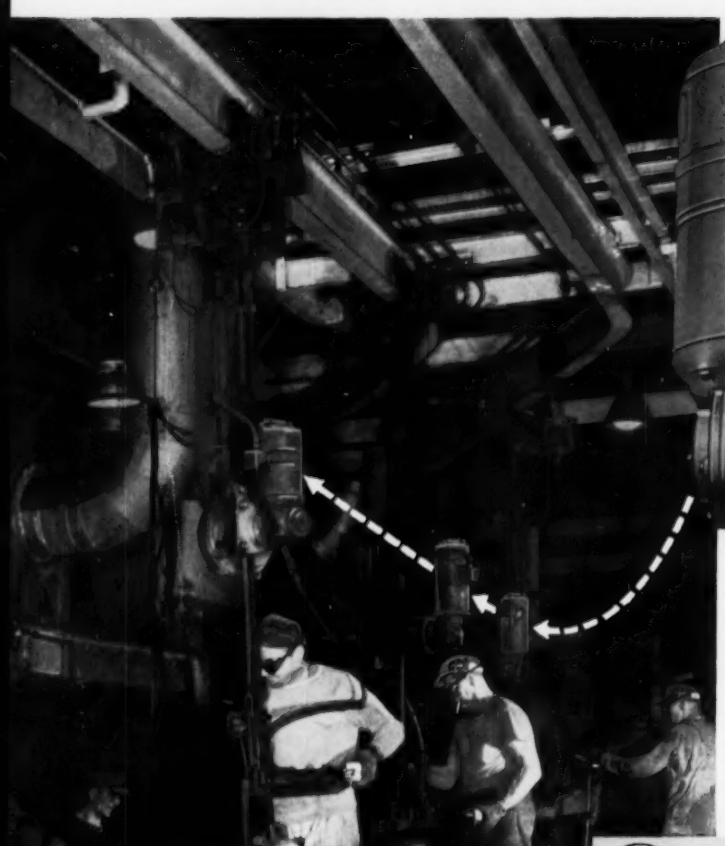
Circle No. 702, Page 167-168

MODERN NEW ELECTRIC POURING!

Electrified pouring devices now are relieving many pour-off men from all lifting and load pushing. Whether your pouring progresses over synchronized conveyor lines (shown here) or on conventional pallets you can enjoy all these cost-cutting benefits;

- ***Less back-breaking work permits the operator to concentrate on faster more accurate pouring . . .***
- ***Fewer relief men are needed . . .***
- ***Higher tonnages are poured with less fatigue . . .***
- ***Chilling waste is nil . . .***
- ***Over-all quality of metal is higher . . .***
- ***Fewer accidents help to reduce insurance rates . . .***

Two sizes are available to handle *gross loads to 1275 pounds (as shown) and another with *gross load capacity to 2400 pounds. The electric pouring devices in operation here are handling 19″ ladles and 400 pounds of molten metal. Complete information will be mailed on your request to MODERN EQUIPMENT COMPANY, Port Washington, Wisconsin.



Over-head traverse is synchronized with conveyor at Neenah Foundry Company. Tag-line may be substituted for conductor bars.

**GROSS LOAD is bail, complete ladle, lining and metal.*

Enlarged view of motor and gear section of new pouring device FAE — shown in operation here.

MODERN

MODERN EQUIPMENT CO., Dept. M-3, Port Washington, Wis.

- ☐ Mail bulletin on new, electric device . . . FAE-11-58
- ☐ Mail catalog on standard pouring devices and ladles . . . P-152-A
- ☐ Mail catalog on water-cooled cupolas and chargers . . . 147-C
- ☐ Ask representative to call.

COMPANY .....

STREET .....ZONE .....BOX .....

CITY .....STATE .....

MY NAME .....

Circle No. 703, Page 167-168

the editor's report

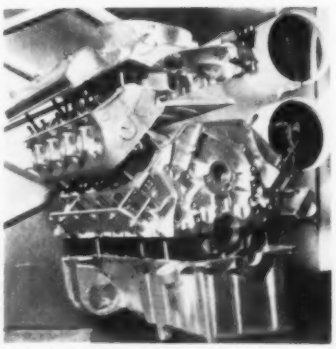
by Jack Schaum

■ **Essential product: training and research** . . the AFS Board of Directors, February 10 unanimously approved construction of a Foundry Training Center building on the site of the AFS Headquarters at Des Plaines, Ill. The Training Center will house all activities of the AFS Training and Research Institute, activated two years ago. Nearly 800 men from over 350 companies have already attended 21 courses conducted in six cities. The carefully planned permanent facilities of the Center will permit a broadening of the T&RI program to meet future demands for qualified, trained personnel. The 18,000 sq. ft. building will include research laboratories, lecture rooms, demonstration laboratories and facilities for the study of x-ray, sand, chemistry, metallography, spectography, patternmaking, machining, metal polishing and mechanical properties.

■ **Did you see at the last AFS Show** . . . the new exothermic-coated steel arc-welding rod for rapidly gouging out burned-in sand, imperfections and inclusions. Exothermic coating produces jet action which continually blows melted metal away from arc. Rod can be bent to any devious shape to reach inaccessible spots.

■ **Hot extruded ductile iron** . . . has been made a reality by the Watertown Arsenal. Extruded rounds and tubes display an excellent combination of strength and ductility — somewhat superior to cast ductile iron. Billets are cast to size and extruded at 1800 F using glass lubrication.

■ **The Cast Aluminum Engine** . . . received lots of attention at the Society of Automotive Engineers' exhibit in Detroit. Center picture emphasizes how the cast-iron block outweighs an Alcoa aluminum block plus one attractive passenger. Sectional picture, on right, displays an Alcoa die cast, or permanent, mold design with integral cylinder walls requiring no liners. Exploded view of BMW engine was exhibited by Reynolds Aluminum Co. at S.A.E. Show. This German-built engine is in production with cast aluminum block, heads, pan and transmission housings. This year the average U. S. car contains 51.58 lb of aluminum—a whopping 283 million-lb total estimated for 1959!



Published by American Foundrymen's Society, Golf & Wolf Roads, Des Plaines, Ill.
VAnderbilt 4-0181
WM. W. MALONEY, *General Manager*

Editorial Staff

JACK H. SCHAUM, *Editor*
PAUL R. FOGHT, *Managing Editor*
GEORGE A. MOTT, *News Editor*
KEITH L. POTTER, *Assistant Editor*
VIRGINIA SUTTERBY, *Production Editor*
MALCOLM SMITH, *Art Director*

Contributing Editors

S. C. MASSARI, *Metallurgical*
H. J. WEBER, *Safety, Hygiene, and Air Pollution Control*
R. E. BETTERLEY, *Educational*

Business Staff

J. M. ECKERT, *Advertising Manager*
CAROL H. ECKLUND, *Advertising Production*
ELAINE E. WALTERS, *Readers Service*

District Managers

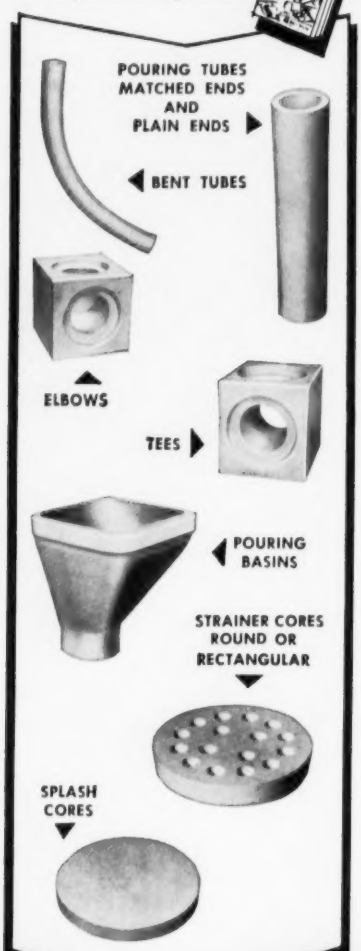
WM. J. ENGLEHART—Cleveland
14805 Detroit Ave.
ACademy 6-2423
JAMES C. KURZ—Midwest
Golf & Wolf Rds., Des Plaines, Ill.
VAnderbilt 4-0181
R. E. MCLOUGHLIN—New York
205 E. 42nd St., Suite 318
LExington 2-7711

Circle No. 703, Page 167-168

UNIVERSAL
REFRACTORY GATING COMPONENTS

• The *Thinwal* construction, providing as much as *35% lighter weight* will not spall nor erode in use even at temperatures up to 3250°F. They eliminate slag inclusions, stop rejects, reduce cleaning room time.

Standards and specifications bulletin available on request. Units for special applications quoted.



UNIVERSAL
CLAY PRODUCTS CO.

1505 First St. • MAin 6-4912 • Sandusky, Ohio

Circle No. 704, Page 167-168

Build an idea-file for improvement and profit. The post-free cards *on the last page* will bring more information on these new . . .

products and processes

PAYROLL TAX COMPUTER . . . reportedly cuts payroll computing time in half. Shows withholding tax and new 2-1/2 per cent social security deductions on one line for weekly wages up to $250. *Calcu-Tax Corp.*

For Manufacturer's Information Circle No. 521, Page 167-168

PLASTIC CORE BOX VENT . . . designed for quick replacement of screen and slotted vents in core boxes and blow plates. Manufacturer states life of plastic vent is up to five times greater than other vents. They can be mounted on vertical walls of core boxes without distorting or restricting removal of cores. *Better Foundry Products*

For Manufacturer's Information Circle No. 522, Page 167-168

FLEXIBLE, ALL-STEEL SANDPAPER . . . provides total of 750 cutting sides per sq. in. Manufacturer states product outlasts conventional sandpaper 10 times, and out-cuts it five to one. Reported to quickly rasp, sand and smooth wood, plaster, plastics and soft metals. *Red Devil Tools.*

For Manufacturer's Information Circle No. 523, Page 167-168

PAINT RESISTS 1000 F . . . made of graphite and silicones, company reports this paint, applied to metal, is capable of withstanding violent thermal shock of 1000 F when plunged into ice water. Shock does not cause paint to crack, peel, flake or bubble. *Joseph Dixon Crucible Co.*

For Manufacturer's Information Circle No. 524, Page 167-168

CHEMICAL BONDING . . . adhesives involving use of two liquids which are mixed just before use to cure the bond by chemical action strength. Company says 3 steel plates, when bonded with 1/4 oz of adhesive, supported 44,000-lb. tractor. *Narmco Resins & Castings Co.*

For Manufacturer's Information Circle No. 525, Page 167-168

LIQUID ALUMINUM . . . can be cast without heat or pressure. Reportedly hardens within two hours after adding hardener. Castable and bonding material. *Devcon Corp.*

For Manufacturer's Information Circle No. 526, Page 167-168

SELF RETRACTING REEL . . . for welding cable pays out easily and is held by locking pawls until released by slight tug on cable. Reel has current capacity of 300 amps, designed to hold 50 ft of 2/0 cable. *United Specialties Inc.*

For Manufacturer's Information Circle No. 527, Page 167-168

AUTOMATIC WEIGHING, HANDLING . . . of mold and core sand additives (dry) possible with unit which selects, weighs and delivers preset weight of any number of additives into common hopper. *Harry W. Dietert Co.*

For Manufacturer's Information Circle No. 528, Page 167-168

SPRING CLAMP . . . provides high tension holding of two or more thicknesses of wood, metal, plastic, fiberglass, etc. Spring completely enclosed to protect operator as well as clamp. Set and released with clamp-setting steel plier. *Wedgelock Corp.*

For Manufacturer's Information Circle No. 529, Page 167-168

HEAVY DUTY BLAST CLEANING . . . machine reportedly increases cleaning speed and flexibility while reducing abrasive loss. Throws 50,000 lb of abrasive per hr. Accommodates loads up to 3500 lb with single pieces weighing up to 800 lb. *Pangborn Corp.*

For Manufacturer's Information Circle No. 530, Page 167-168

METAL COATING . . . for precision castings permits coating before milling or machining. Applied by either dipping or spraying, and then baked for permanent, durable finish which is not affected by machining. *J. Landau & Co.*

For Manufacturer's Information Circle No. 531, Page 167-168

FORK LIFT CONVERSION . . . attachment designed to transform any fork truck into mobile overhead lifting unit. Simplifies moving of heavy loads. No wrenches or adjustments required in attaching or removing device. *Merrill Brothers.*

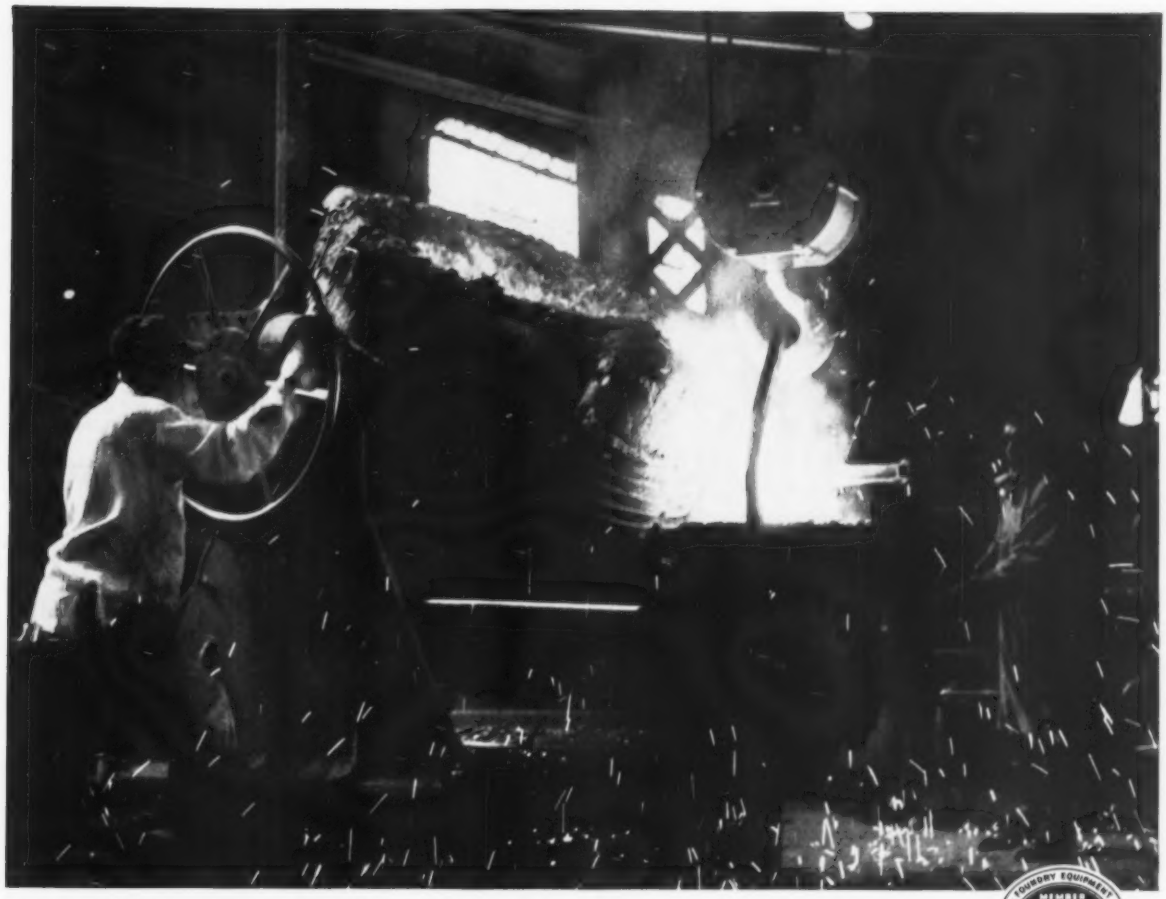
For Manufacturer's Information Circle No. 532, Page 167-168

MASONRY SAWS . . . reportedly cut precision-perfect shapes on refractories. *Selas Corp. of America.*

For Manufacturer's Information Circle No. 533, Page 167-168

FERROALLOYS . . . with minimum 75 per cent chromium content and maximum carbon of 0.015 or 0.025 per cent

Continued on page 8



Every inch a ladle...

"Teapot spout" pours clean without skimming!

A Chicago foundry distributes clean molten metal every time with this *Whiting Teapot Spout Ladle*. Easy to operate, there's no skimming required because floating slag forms a crust to keep heat *in* and temperature right for bottom pour. Easy to maintain, the simple spout arrangement is independent of bowl, can be relined without disturbing bowl proper!

Whiting Ladles of all types and sizes are designed to speed output, minimize labor and improve quality of foundry castings. Built to withstand the rigors of year in, year out service, they feature steel spouts, riveted or welded heads and specially designed bowl reinforcement.

SEND FOR NEW LADLE HANDLER BULLETIN FY-178R

... it details the way to maximum pouring ease and complete operator safety now gained with all-new Whiting Ladle Handler. Be sure to add this bulletin to your important literature file now! *Whiting Corporation, 15628 Lathrop Ave., Harvey, Ill.*

87 OF AMERICA'S "FIRST HUNDRED" CORPORATIONS ARE WHITING CUSTOMERS

75th year

WHITING

FOUNDRY EQUIPMENT

MANUFACTURERS OF CRANES; TRAMBEAM HANDLING SYSTEMS; TRACKMOBILES; FOUNDRY, RAILROAD AND CHEMICAL PROCESSING EQUIPMENT

Circle No. 705, Page 167-168

say "when"!

with MARSHALL ENCLOSED-TIP THERMOCOUPLES

. . . for strong, dense, uniform castings from every melt!

Reduce scrap rejects, misruns, cold-shuts . . . achieve consistently high quality castings! Marshall Enclosed-Tip Thermocouples indicate instantly and accurately "when" to pour brass, bronze, aluminum, or magnesium melts. Frequent, regular, exact temperature readings help avoid shrinkage porosity, gas porosity, dross . . . produce better casting finishes . . . control aluminum grain size.

Dependable, easy-to-use Marshall Thermocouples *take interior temperatures deep within the melt.* Tip can be stirred to speed reading, giving *true temperature in about 20 seconds.* Pyrometer always indicates *steady, accurate reading.* Thermocouple wire can't become contaminated from melt or short-circuited by slag. Tip withstands scores of immersions before replacement is necessary. Mail coupon for catalog today!

L. H. MARSHALL CO.

270 WEST LANE AVE., COLUMBUS 2, OHIO

Furnace Type (above) . . . lengths up to 10 ft., for use with Stationary Pyrometer.
Ladle Type (left) . . . for use with Portable Pyrometer.

L. H. MARSHALL CO., 270 W. LANE AVE., COLUMBUS 2, OHIO

Please rush Catalog which fully describes Marshall Enclosed-Tip Thermocouples!

NAME_____

FIRM_____

STREET ADDRESS_____

CITY_____

Circle No. 706, Page 167-168

products and processes

Continued from page 6

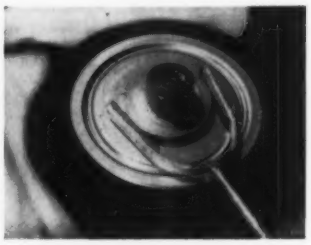
designed for foundries producing stainless steels and high temperature alloys. Reportedly offers lower transportation and materials handling costs, and less cooling of metal. *Vanadium Corp. of America.*

For Manufacturer's Information Circle No. 534, Page 167-168

VARIABLE SPEED DRIVE . . . assembly designed to provide speed ratios from 1 to 1 to as high as 25 to 1. Output speed varied by turning handwheel on adjustable motor base. Well suited for cut-off saws, welding positioners, polishing machines, banding machines and grinding machines. *Variable Speed Drive Assemblies.*

For Manufacturer's Information Circle No. 535, Page 167-168

ABRASIVE FEED MECHANISM . . . feeds additional abrasive to grinding and polishing head while head is in motion. Five-hundred lineal inches of abrasive, coiled inside brushed-backed head, is



metered out in proper amount automatically by applying pressure to external ring with simple tool for that purpose. *Grinding & Polishing Machinery Corp.*

For Manufacturer's Information Circle No. 536, Page 167-168

FRONT-END LOADER . . . rear-wheel drive, front-wheel steer, carry capacity of 3000 lb. Bucket sizes, 2/3 to 2 cu yds. Full 40 degree tipback claimed to allow larger loads than formerly possible. *Frank G. Hough Co.*

For Manufacturer's Information Circle No. 537, Page 167-168

FLAME-PROOF CLOTHING . . . said to combine soft, lightweight feel of cotton with flameproofing, plus providing up to 3 times the wear of untreated cotton. Reportedly can be laundered or dry-cleaned 10 times without effecting flameproofing. *American Optical Co.*

For Manufacturer's Information Circle No. 538, Page 167-168

SAFETY TREAD COATING . . . applied by brush or squeegee cures for traffic in a few hr. Kit includes plastic resin, activator and shaker-top can of abrasive grit. *Ring Chemical Co.*

For Manufacturer's Information Circle No. 539, Page 167-168

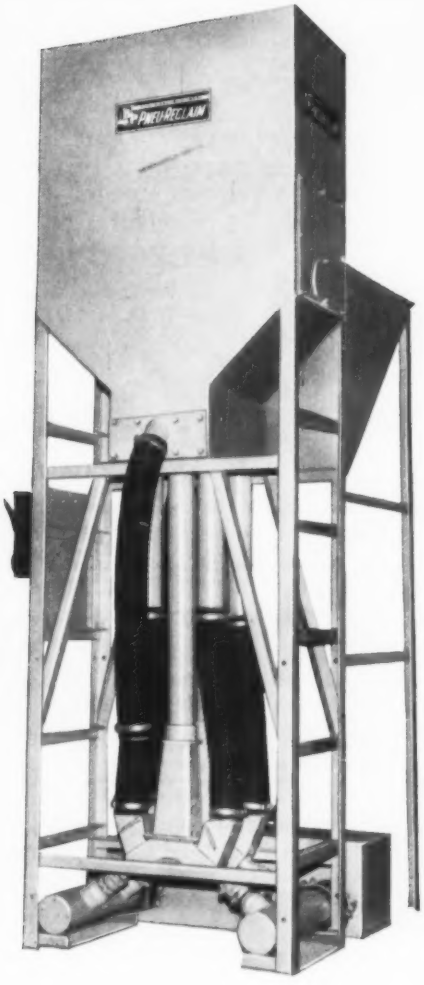
STIRRING RODS . . . skimmers and crucible covers of graphite. Stirrers facilitate mixing melt, adding alloys or deoxidizers covers reportedly provide ex-

Continued on page 10

BY ACTUAL COUNT*

* Based on the actual number of units sold during 1958 by all manufacturers, three out of every four dry sand reclamation units sold were B & P Pneu-Reclaim.

3 out of 4 reclamation units sold are PNEU-RECLAIM



Here—for the first time—is a unit economical enough for gray iron and non-ferrous foundries, as well as steel and malleable plants. Now all foundries can save through dry sand reclamation. CO_2, airsetting and shell sands as well as conventional facing, molding and core sands are reclaimed for reuse.

HERE'S WHY

1. **Higher degree of reclamation**—exclusive features like B&P Level Flow and Dual Jet Scrubbing permit Pneu-Reclaim to handle "problem sands" that cannot be reclaimed efficiently by other units.

2. **Lower Maintenance Costs**—fewer wearing parts, greater accessibility. In Pneu-Reclaim a vertical tube can be changed by one man in 20 minutes—less than one-sixth the labor requirement for the same maintenance job in other units.

3. **Lower Operating Costs**—Pneu-Reclaim with exclusive Dual Jet Scrubbing requires only half the air velocity, and therefore half the power cost of other units. Lower air velocity cuts wear, too.

4. **Less Space Required**—modern Pneu-Reclaim design requires less space and less headroom. Pneu-Reclaim can fit into limited areas that could not accommodate other units.

5. **More Flexibility**—Pneu-Reclaim can fit into existing sand systems or be used as a separate package. Because of its designed *flexibility*, it can actually be installed for far less.

6. **Highest capacity per dollar invested**—Pneu-Reclaim's Dual Jet Scrubbing provides appreciably higher capacity per square foot of floor space, or per dollar invested.

Write today for a free fact booklet

BEARDSLEY & PIPER

Div. Pettibone Mulliken Corp., 2424 N. Cicero Avenue
Chicago 39, Illinois

Circle No. 707, Page 167-168

another perfect pitch for cleaner iron with

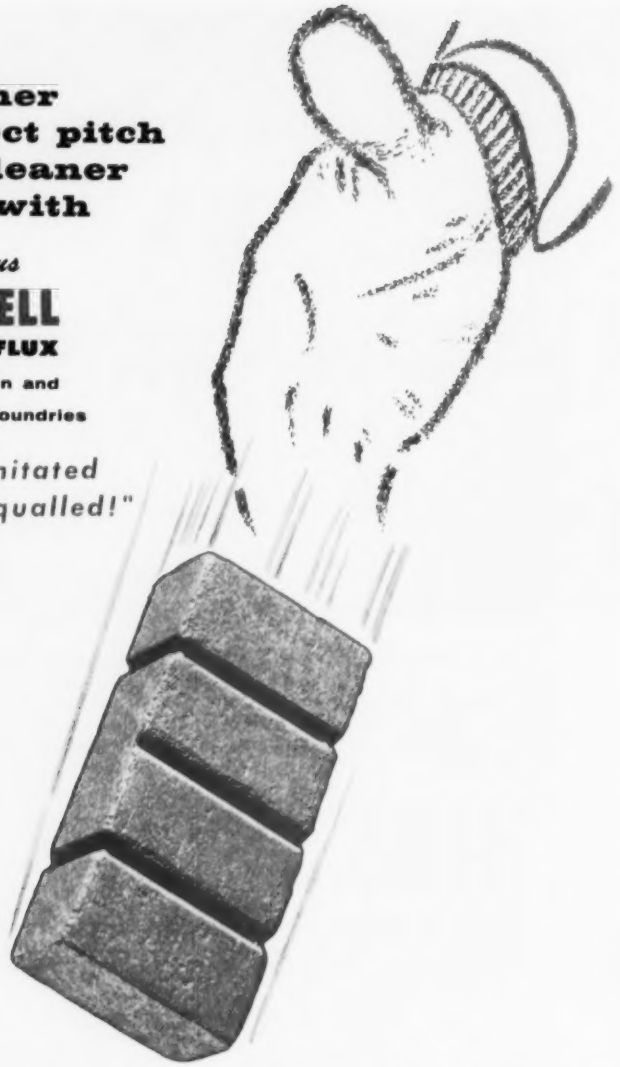
Famous

CORNELL

CUPOLA FLUX

for Gray Iron and Malleable Foundries

"often imitated never equalled!"



Just toss a quarter, half or full brick, depending on the size of the charge of iron, into the cupola. It's just that easy. Yet, Famous Cornell Cupola Flux will increase the amount of slag that floats off. Drops are cleaner, saving you time and money in digging out time. Best of all, castings have greater tensile strength and are uniformly hard throughout. Write for Bulletin 46-B.

P.S. If you melt Aluminum, Copper or Brass, try Famous Cornell Aluminum, Copper or Brass Flux.

Write for Bulletin 46-A.

DAWSON-MacDONALD CO.
141 PEARL STREET, BOSTON 10, MASS.
Now Representing The Cleveland Flux Company in New England.

FAMOUS CORNELL FLUXES

Trade Mark Registered

The* CLEVELAND FLUX *Company

1026-40 MAIN AVENUE, N. W. • CLEVELAND 13, OHIO

Manufacturers of Iron, Semi-Steel, Malleable, Brass, Bronze, Aluminum and Ladle Fluxes—Since 1918

Circle No. 708, Page 167-168

products and processes

Continued from page 8

tra precaution against contamination from gases or foreign materials. Covers float on molten metal and can be removed with most of slag before pouring. *Vesuvius Crucible Co.*

For Manufacturer's Information Circle No. 540, Page 167-168

SILICON CARBIDE . . . for direct addition to gray and malleable iron cupolas offered in steel containers said to fully protect additive until it reaches signifi-

cant melting zone of cupola. Company officials state every lb goes into solution eliminating waste. *American Metallurgical Products Co.*

For Manufacturer's Information Circle No. 541, Page 167-168

COST CONTROL . . . in operation of weighing furnace charges facilitated by new scale offering printing of weight

data in large figures on office forms or tickets up to 8-1/2 x 11-in. size. *Toledo Scale Corp.*

For Manufacturer's Information Circle No. 542, Page 167-168

METAL MARKER . . . is ball-point marking tube for permanent coding of castings as well as wood, plastic and glass. Manufacturer states fast-drying ink withstands heat and weathering, and will not chip, peel, fade or rub off under adverse conditions. Available in seven colors. *John P. Nissen, Jr. Co.*

For Manufacturer's Information Circle No. 543, Page 167-168

ELECTRIFIED POURING . . . devices newly designed to eliminate lifting and pushing of ladles during pour-off operation. Two sizes for gross loads of 1275 lb and 2400 lb. *Modern Equipment Co.*

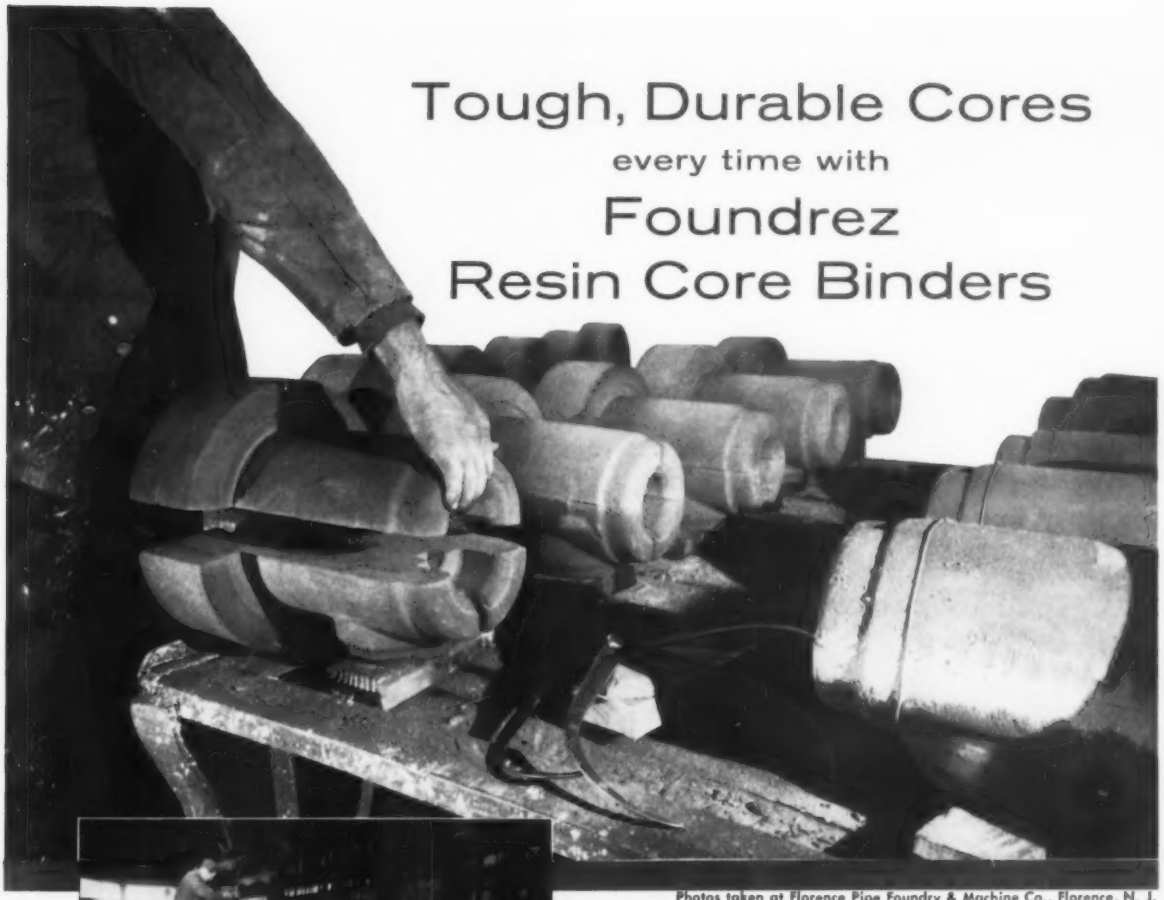
For Manufacturer's Information Circle No. 544, Page 167-168

Continued on page 12

Tough, Durable Cores

every time with

Foundrez Resin Core Binders



Photos taken at Florence Pipe Foundry & Machine Co., Florence, N. J.

Volume production of heavy castings demands that the cores used by Florence Pipe Foundry & Machine Company stand up under rough handling. Florence secures the high tensile strength and hardness needed in these cores by using RCI FOUNDREZ 7100 series resin binders in their molding sand.

These water dispersible phenol-formaldehyde core binders are especially formulated for use where baking time is at a premium. In addition they possess higher hot strength and slower collapsibility than either core oils or urea-formaldehyde binders.

These resins are used in conventional core sand mixtures containing cereal binders and water. Only half as much FOUNDREZ as regular core oil is required to produce equivalent core handleability. Reichhold's FOUNDREZ 7100 series includes:

Foundrez 7101 — a high solids binder compounded for foundries where core gas is a problem. Extremely effective in producing cores with high strength and hardness.

Foundrez 7102 — formulated for very rapid baking schedules, this binder provides excellent green strength with a minimum of cereal binder.

Foundrez 7103 — features easy collapsibility and a low viscosity which permits ready mixing.

Foundrez 7104 — combines a high degree of stability with high tensile strength. Resultant cores are extremely moisture resistant — may be stored for long periods without fear of moisture pickup.

For complete technical data on the FOUNDREZ 7100 line write Reichhold — ask for Bulletin F-1-R.

Creative Chemistry . . .
Your Partner in Progress

RCI

REICHHOLD

FOUNDRY PRODUCTS

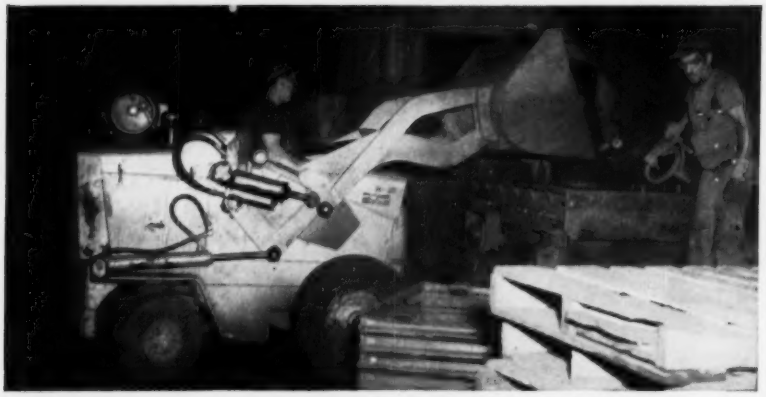
FOUNDREZ — Synthetic Resin Binders

COROVIT — Self-curing Binders • coRCIment — Core Oils

REICHHOLD CHEMICALS, INC., RCI BUILDING, WHITE PLAINS, N. Y.

Circle No. 709, Page 167-168

PAYLOADER® maneuverability



"Power-steering makes a big difference

. . . works faster in close quarters"

That's one of the significant comments of J. T. Williams, plant manager and Edwin Daugs, "PAYLOADER" operator, of Grede Foundries Inc. at Reedsburg, Wis., concerning their model H-25. This Milwaukee company, with seven plants in the Midwest, has enjoyed many years of profitable experience with "PAYLOADER" tractor-shovel use in their steel, gray iron, ductile iron and alloy iron casting operations.

The Reedsburg product is ductile iron and its Model H-25 has important duties there day and night. It breaks the molds on the floor, then picks up sand and castings and delivers them to the shakeout. It takes used sand to the muller and delivers 30-35 loads of reconditioned sand per hour to the molding stations . . . also hauls limestone and coke.

Power-steering is one of the many features of the new H-25 "PAYLOADER" that makes it more productive. Its 2,500 lbs. carry capacity is 25 to 50% more than has heretofore been available in a 6-ft.-turning-radius tractor-shovel. It has power-shift transmission for fast, easy shuttling and maneuvering and including exclusive two-speed ranges in reverse. Power-transfer differential is another exclusive in its size class — a feature that transfers more power to the other drive wheel when one of them gets on slippery or loose footing. It reduces wheel-spinning, time-wasting inaction.

Your Hough Distributor is ready to show you all the other superior advantages of the new Model H-25 — why it is the most productive and most durable tractor-shovel anywhere near its size.

HOUGH®

THE FRANK G. HOUGH CO.
LIBERTYVILLE, ILLINOIS
SUBSIDIARY — INTERNATIONAL HARVESTER COMPANY

THE FRANK G. HOUGH CO.
711 Sunnyside Ave., Libertyville, Ill.

☐ Send H-25 PAYLOADER data.
☐ Other PAYLOADER models.

Name _____ Title _____
Company _____
Street _____
City _____
State _____

3-A-2

Circle No. 710, Page 167-168

products and processes

Continued from page 10

DEBURRING AND FINISHING . . . tool designed for finishing of protruding radii and convex surfaces of castings. Portable, lightweight belt grinder has

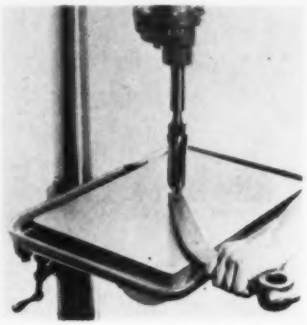
three working surfaces, adjustable for large or small radii. *Peterson Tool & Mfg. Corp.*

For Manufacturer's Information Circle No. 545, Page 167-168

FILLETING COMPOUND . . . 100 per cent epoxy resin useful in repairing leaks in core boxes, enlarging gates, filling a crack where the gate meets the pattern or for general filleting purposes. *Carl H. Biggs Co.*

For Manufacturer's Information Circle No. 546, Page 167-168

SLOW-SPEED ATTACHMENT . . . reduces drill press rpm's. Attachment for 20-in. drill press provides smooth,



high torque power transmission for spotfacing, reaming, counterboring and core drilling operations. Attachment offers five speeds. *Rockwell Mfg. Co.*

For Manufacturer's Information Circle No. 547, Page 167-168

ELECTROMECHANICAL VIBRATING SCREEN . . . designed to handle materials from 100 mesh to 3-in. lumps. Two new models, 4 by 6-ft screen surface; and 5 by 10 ft. *Syntron Co.*

For Manufacturer's Information Circle No. 548, Page 167-168

this cleaning room hand will soon clean up with what he's learned by using our circle numbers to send for manufacturer's literature

COMPLETE is the word for it!

A Time Tested (Since 1940) Foundry Planning and Engineering Service to Guide Management to PROFITABLE Operation.

As a Foundryman, you are doubtless aware of the industry's many hazards and its sensitivity to mechanical, human and economic elements.

EXPERIENCE and KNOWLEDGE are ESSENTIAL in a business of this type, particularly when new construction, modernization or expansion is planned.

FODECO's staff has been built to serve the foundry industry in ALL of its functions. Our programs are engineered by men who know foundries. We can help you with:

1. **Design and layout**
2. **Raw materials and their handling**
3. **All production methods**
4. **Metal control for specific properties**
5. **Overhead and profits**

Let us inspect your plant and discuss your program with you, at no cost or obligation, of course.

Telephone, write or wire

FOUNDRY DESIGN CO.

106 South Hanley Road · St. Louis 5, Missouri · Telephone: VOlunteer 1-5277

Circle No. 711, Page 167-168

Lindberg-Designed

furnaces, more than 75 of them, help Ford Motor Company maintain casting production and quality standards

The new Aluminum Castings Plant of Ford Motor Company, Engine and Foundry Division, at Sheffield, Alabama, is a model of modern production efficiency. Contributing to its effective operation is a huge battery of Lindberg-Fisher aluminum holding furnaces, more than 75 of them. Eight large 65,000 lb. capacity reverberatory holding furnaces receive molten aluminum delivered from an adjacent Reynolds Metals plant and hold it at the desired temperature. Six other reverberatory furnaces, each with 20,000 lb. capacity, are used for remelting scrap aluminum from trimmed parts and holding metal at its usable temperatures. Molten metal is then delivered to more than 60 electric resistance holding furnaces in the casting area as needed. This unique installation, developed by Ford engineers in conjunction with Lindberg, is a major factor in maintaining the high quality product and production standards required by Ford.

Lindberg equipment and Lindberg planning can help you find the most effective answer to any problem of applying heat to industry. We cover the field, melting and holding, heat treating, tempering, brazing, enameling furnaces, ceramic kilns, high frequency units, and are in the ideal position to recommend just the type of equipment most suitable for your needs. This can be factory built or field-installed in your own plant, fuel-fired or electric. Consult your local Lindberg Field Representative (see the classified phone book) or get in touch with us direct. Lindberg-Fisher Division, Lindberg Engineering Company, 2440 West Hubbard Street, Chicago 12, Illinois. Los Angeles Plant: 11937 South Regentview Avenue, at Downey, California.

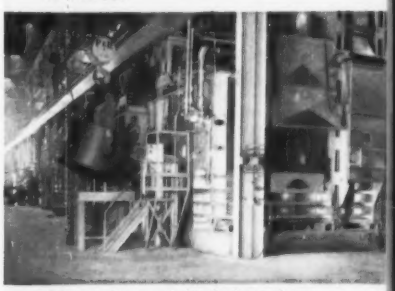
SEE LINDBERG IN BOOTH NO. 660 at the WESTERN METAL CONGRESS

Handsome entrance to new plant of Ford Motor Company, Sheffield, Alabama.

Metal temperatures are positively controlled through Lindberg Control Panel.

Some furnaces are arranged for hand ladling and others are equipped with Lindberg Autoladle.

Molten aluminum is delivered direct to reverberatory holding furnaces.



The molten metal is held in these 14 huge furnaces for distribution to the casting areas.

LINDBERG heat for industry

Circle No. 712, Page 167-168

pouring off the heat

happy sighs over size

■ I have just finished reading the January issue of the new MODERN CASTINGS. You and your entire staff are to be congratulated for a job well done. You have reduced the size, but you have not reduced the quality. In my book, it is "king size" in every detail. The technical articles, the AFS News section, in fact the whole format of this new magazine is excellent in every respect.

All members of AFS should be proud of the new MODERN CASTINGS.

FRANK W. SHIPLEY
Caterpillar Tractor Co.
Peoria, Ill.

■ I wish to congratulate you and all the staff for the new look. Everything from the features through the AFS News section was presented in a way that appealed to me. In fact, I cannot recall an issue that has impressed me to such an extent.

JOHN H. KING
Archer-Daniels-Midland Company (Canada) Ltd.
Toronto

■ The new size of the magazine is perfect!

J. G. RAMSTROM
Wentworth Institute
Boston

■ I like the new format, and this issue was also particularly good.

G. E. SEAVOY
Whiting Corp.
Harvey, Ill.

■ I wish to congratulate you on a very good job.

K. D. MILLIS
The International Nickel Co.
New York

■ I heartily approve of the sensible size of the book.

PETER E. RENTSCHLER
The Hamilton Foundry & Machine Co.
Hamilton, Ohio

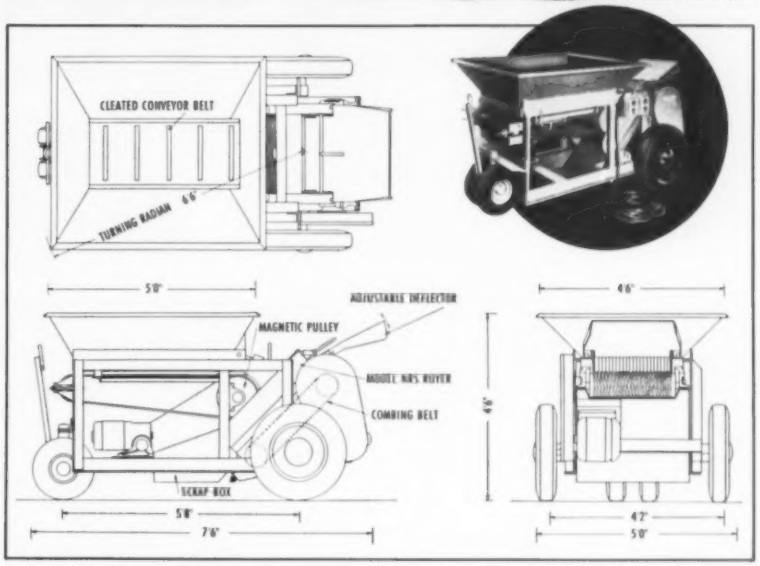
■ The magazine size makes it much easier to clip the magazine for files containing items and articles which I am preserving.

C. E. WESTOVER
Westover Corp.
Milwaukee

SAND CONDITIONING TOPICS

PUBLISHED BY ROYER, MANUFACTURERS OF THE FOREMOST IN SAND CONDITIONING EQUIPMENT

ROYER



Sand Conditioning costs can be reasonable

When any industry suffers a business recession, however slight, the attention of its leaders automatically shifts to cost cutting and the elimination of waste. Many foundrymen peer wistfully at the large, highly mechanized foundry and imagine semi-automation is the answer.

Looking at the foundry industry realistically, this form of advanced mechanization is not the answer. Seventy-two per cent of the nation's foundries employ less than 50 men—for most of these, advanced mechanization is both a physical and an economic impossibility.

For these foundries, units like the highly efficient Royer MAGNA-SAN are the practical solution to most sand conditioning cost problems. Here is a unit that is foundry-engineered to magnetically clean, mix, blend and aerate shakeout sand right on the molding floor—and at a lower initial cost and with less maintenance than any other mechanical method.

The Royer MAGNA-SAN is ideally designed for use in the small and medium sized foundry—this 73 per cent who most need the advantages of mechanization but cannot pick up the bill. Compare this compact unit, in the drawing above, with your available working space. Notice how the compact design permits easy maneuvering about crowded casting floors.

Capacity-wise, the Royer MAGNA-SAN conditions 45 tons of sand per hour—a full 8 per cent more than its closest competitor. And remember, it is a fact that economy of operation is determined by performance, which is measured by comparative expense per ton of sand conditioned.

We invite you to see for yourself how reasonable sand conditioning costs can be. Send the coupon and we'll rush your copy of the MAGNA-SAN Bulletin RM57 to you by return mail.

ROYER FOUNDRY & MACHINE CO.

ROYER 155 PRINGLE STREET KINGSTON, PENNA.

I want to know more about reasonable sand conditioning costs. Rush me your MAGNA-SAN Bulletin.

NAME_____

COMPANY_____

ADDRESS_____

CITY_____ ZONE_____ STATE_____

Circle No. 713, Page 167-168

Sure, I've been running this core room since you were in knee britches. But my boss doesn't hire whiskers; he wants performance—the right cores for the job. And the work here varies all over the lot. I stay right up to date on binders, processes and brands, so—

don't call me an

OLD TIMER!

Circle No. 714, Page 167-168

We're using all three, aren't we?

LINOIL...for oil-sand cores
LIN-O-SET...for air setting
ADCOSIL...for CO_2 gas curing

This is a jobbing foundry. We sell custom castings at a profit—some involve intricate high production core work; others call for massive chunk cores. Our production dictates what cores are needed, and it's up to me to have the right cores on the floor at the right time.

That means flexibility, and in our case, three processes: conventional, air setting, and CO_2.

Back when I was an apprentice core maker, LINOIL was the oil we depended on. I still count on LINOIL for our baked cores because I get consistent quality and uniformity—cores are strong and hard and they shake out like sugar. I can make a selection from a wide range of LINOILS for any type job.

LIN-O-SET came along just in time to save us time and money in the fabrication of large cores. Our chunk cores now take half as much time to make and a third less time to bake. Helps offset increased costs. Cuts rodding and cleaning in half, too!

ADCOSIL, ADM's CO_2 core binder, works like magic to cure intricate cores instantly and thoroughly. Ideal for blown cores. ADCOSIL with color indicator tells us where to place core vents and helps us rig new boxes and patterns.

I'm no OLD TIMER... We're up to date, boy! We buy ADM-Federal core binders for any and all processes! What's more, we buy smart... always order mixed truckloads and get lowest price, as well as reducing our freight costs.

... Archer-Daniels-Midland company
FEDERAL FOUNDRY SUPPLY DIVISION
2191 West 110th Street · Cleveland 2, Ohio

Circle No. 714, Page 167-168

SYNTRON

VIBRATING SCREENS

provide efficient, dependable low cost screening and reclaiming of foundry sand

SYNTRON designs and builds a screen for every foundry need—conditioning and reclaiming foundry sand, conveying and shakeout of castings, and screening and conveying sand and scalped materials.

SYNTRON Vibrating Screens are available in a variety of styles and sizes for every screening application.

SYNTRON Vibrating Screens provide uniform vibration eliminating dead spots. They combine constant full screen efficiency, dependability of operation and low maintenance to give better separation, uniform control and greater tonnage at lower cost.

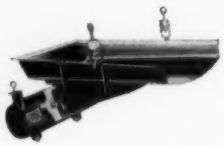
SYNTRON Screens are easy to install; easy to maintain.

Write for complete catalog data on all SYNTRON Screens.

SYNTRON COMPANY
545 Lexington Avenue — Homer City, Penna.

Other SYNTRON Equipment of proven dependable Quality

BIN VIBRATORS



VIBRATORY FEEDERS

HOPPER LEVEL SWITCHES

DRY FEEDER MACHINES

COUNTER BALANCED CONVEYOR SCREENS

Circle No. 715, Page 167-168

pouring off the heat

Continued from page 15

■ I would like to congratulate the Society on their decision. I am sure that the present change will please all readers of your useful magazine.

J. W. MEIER
Physical Metallurgy Division
Department of Mines
and Technical Surveys
Ottawa, Ontario

■ Congratulations! MODERN CASTINGS is an excellent journal, we pass it around to many here in the office.

JOHN W. KELIN
Federated Metals Div.
American Smelting and Refining Co.
Whiting, Ind.

commendations

■ The Material Handling Institute, Inc. thinks you did a fine job with the comprehensive attack on material handling (MODERN CASTINGS, November).

W. L. REDDING
The Materials Handling Institute, Inc.
Pittsburgh, Pa.

thanks a thousand

■ I wish to add my personal congratulations on your excellent presentation of the article "Modernization Permits an Exclusive Product at Tyler Pipe & Foundry", in the January issue.

As part of our program of informing our employees of all of our activities we will send each a copy of the article if 1,000 reprints are available.

D. K. MEKIE
Tyler Pipe & Foundry Co.
Tyler, Texas

export business

■ I read with pleasure and interest the article "Work Simplification is Organized Common Sense" by E. F. Pierce, Lynchburg Foundry Co., in the October issue. I request permission to publish the article in our magazine, L'Automazione.

C. ROSSI
Associazione Nazionale Italiana
Per L'Automazione
Milan, Italy

request answered

■ I would like to thank you for sending my students information that they requested on the patternmaking industry. It aided them to understand the industry and in preparing their out-of-school assignment.

M. J. MARTIN
Amherst Central Junior High School
Snyder, N. Y.

VOLCLAY BENTONITE

NEWSLETTER No. 60

REPORTING NEWS AND DEVELOPMENTS IN THE FOUNDRY USE OF BENTONITE

DROP-OUTS OR DROPS

When deformation is lost in a foundry sand mixture, a high percentage of drops (drop-outs) occur. Stickers to the pattern become more prevalent. Poor lifts develop throughout the foundry where pattern drafts are narrow.

Over ramming occurs with a western bentonite bonded sand mixture which lacks deformation, hence expansion defects may occur. Cellulose materials are then added to prohibit harder ramming. These cushion ramming.

If a pattern has many deep pockets or close tolerance draws, **the measurement of deformation is most important.** If the deformation is too great, the sands may be too gummy to ram properly. **If the sand mixtures possess normal deformation supplied by a reliable western bentonite such as VOLCLAY,** the deformation is satisfactory for lifting such pockets.

Those western bentonites which claim only green compression strength, may lack deformation, they may over-ram. It may require excess additions of expensive cereal to increase deformation to aid drawing of the pattern. Poor lifts occur when the sand mixture packs too tightly in the pattern by lack of deformation.

Do not judge a western bentonite by only green compression strength! If it lacks deformation, it will probably function more as a southern bentonite than a western bentonite.

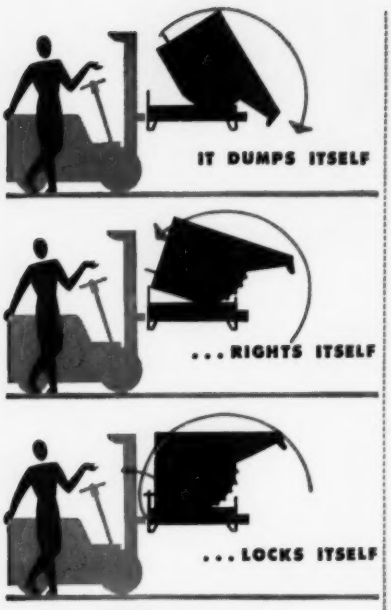
VOLCLAY possesses all satisfactory properties of a western bentonite, yet does not attempt to excel **in only a single property. Deformation is one of the basic properties** of a western bentonite which must be considered when purchasing. **Do not forget VOLCLAY has been time-tested!**

Write For News Letter No. 33 — "Poor Lifts"

AMERICAN COLLOID COMPANY

SKOKIE, ILLINOIS • PRODUCERS OF VOLCLAY AND PANTHER CREEK BENTONITE

Circle No. 716, Page 167-168



This hopper and your truck can cut handling costs 50%

It's a self-dumping hopper made for fast, efficient handling of wet or dry, hot or cold bulk materials, such as:

Scrap Metal . . . Cinders
Cullet . . . Hot Forgings
Punch Press Parts
Soybean Meal . . . Pickles

Hundreds of industries use thousands of them. Pick-up is swift and simple. Forks or platform of any standard lift truck slide easily into hopper underframe. Truck operator picks up loaded hopper . . . transports it to its destination . . . trips the latch . . . and the Roura does the rest . . . automatically.

They're strong . . . husky . . . made of 3/16" steel plate with continuous arc-welded seams. Also available in stainless steel or galvanized. Made in five sizes, ½ to 2 yard capacities, with live skids or a choice of wheels.

Standard models are available for immediate shipment from stock.

ROURA
Self-Dumping
HOPPER

WANT MORE DETAILS on how you can save money with Roura? Just clip this coupon . . . attach it to your letterhead . . . sign your name . . . and mail to

ROURA IRON WORKS, INC.
1414 Woodland Ave., Detroit 11, Michigan

Circle No. 717, Page 167-168

dietrich's corner

by h. f. dietrich

The recent business depression has emphasized the importance of salesmanship. All over the country the sales managers are calling the boys together for pep talks. They gather to brag about their accomplishments, and to sing, "We are the Happy Salesmen. Rah! Rah! Rah!" But, I wonder how many really enjoy the job.

Many of my best friends in the foundry business are peddlers of the old school. One of the best was Old Joe. If salesmen are dynamos of energy with a knack for telling stories and drinking Scotch, Joe was not a typical salesman. In all the years I knew him, he was never in a hurry. While the younger men burned themselves out, Joe plodded along, year after year, serving the foundrymen in his territory. He didn't object to Scotch guzzlers, but hiding behind doctor's orders, he drank only malted milk or ginger ale.

Joe's interest in people, and his remarkable memory, allowed him to gather biographical facts about everyone in his territory. Yet, I never heard him make deliberately disparaging remarks about anyone. If you needed a specialist, Joe knew someone who could fill the job. If you had lost track of a friend, Joe knew where he was working. He knew the capabilities of men from the top brass to the shakeout pit. At the same time, he knew about the hazards of every job opening in his territory. By dealing in the open and never pirating workmen, he was a dependable walking placement bureau.

Some of the car-load-lot boys made remarks about the small orders Joe would handle. Although he was happy with car load orders, Joe never knowingly over-sold a foundryman. If you wanted a used cupola shell, or a tumbler, he knew where to find it. A small foundryman could depend on him for market advice, but never for dangerously over-extended credit. His orders seldom kicked back from the credit department.

Although Joe traveled on a dependable schedule, he always seemed to find time to talk to the men in the shop. He seemed genuinely interested in everyone's progress. He enjoyed hearing about promotions, or other successful enterprise, and he felt bad if some promising young foundryman hit the skids.

Joe was never a lavish entertainer. If he happened to arrive at your foundry near mealtime, he would make you feel that you would do him a favor to lunch with him. A dinner with Joe never left the impression that he was fulfilling a duty.

Good business conditions and the advent of large foundry organizations have closed the shop doors to the traveling salesman. Only in the small foundry can he become a personality instead of a traveling catalog. Not only has the man in the shop lost a contact with the outside world, but the salesman has lost his grass roots contact. He has lost an opportunity to learn about the use of his products. His only sense of service is represented by his filled order book. This becomes a criterion of his success.

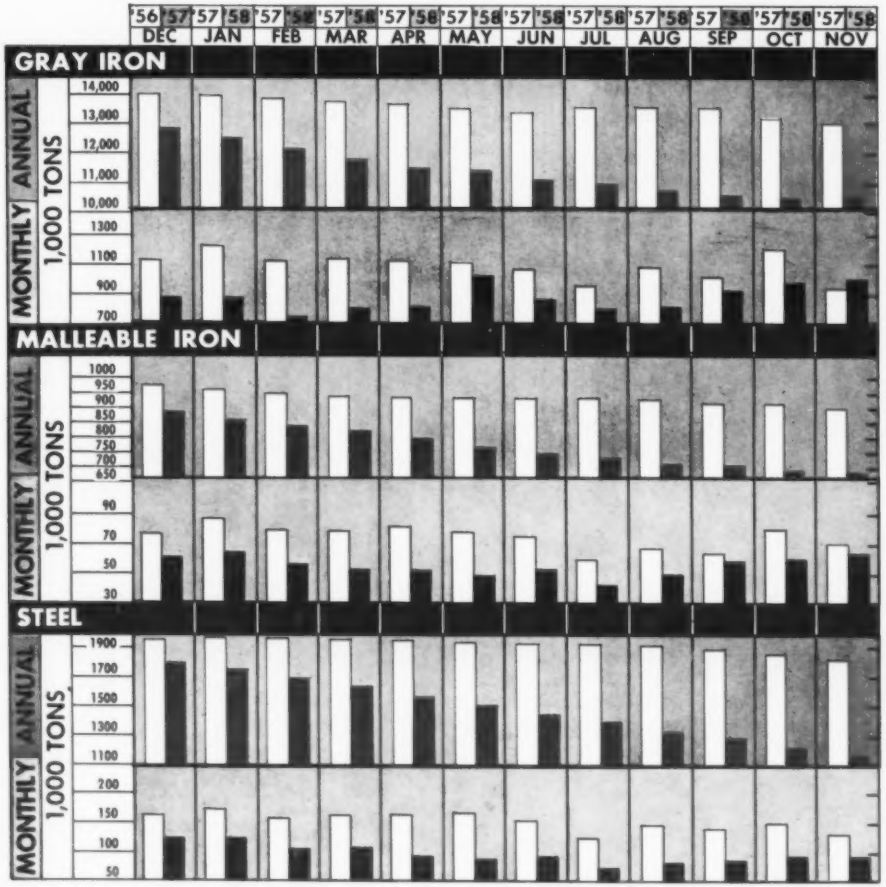
Although Joe never made a lot of money, I felt he really enjoyed life and his job. His was a personalized salesmanship. If some of the hot shot, high pressure, car-load-lot order mechanics wonder why a foundryman waits for a certain salesman, it might be because they are in competition with a salesman like Joe, a man who thoroughly and genuinely enjoys being of service to his clientel.

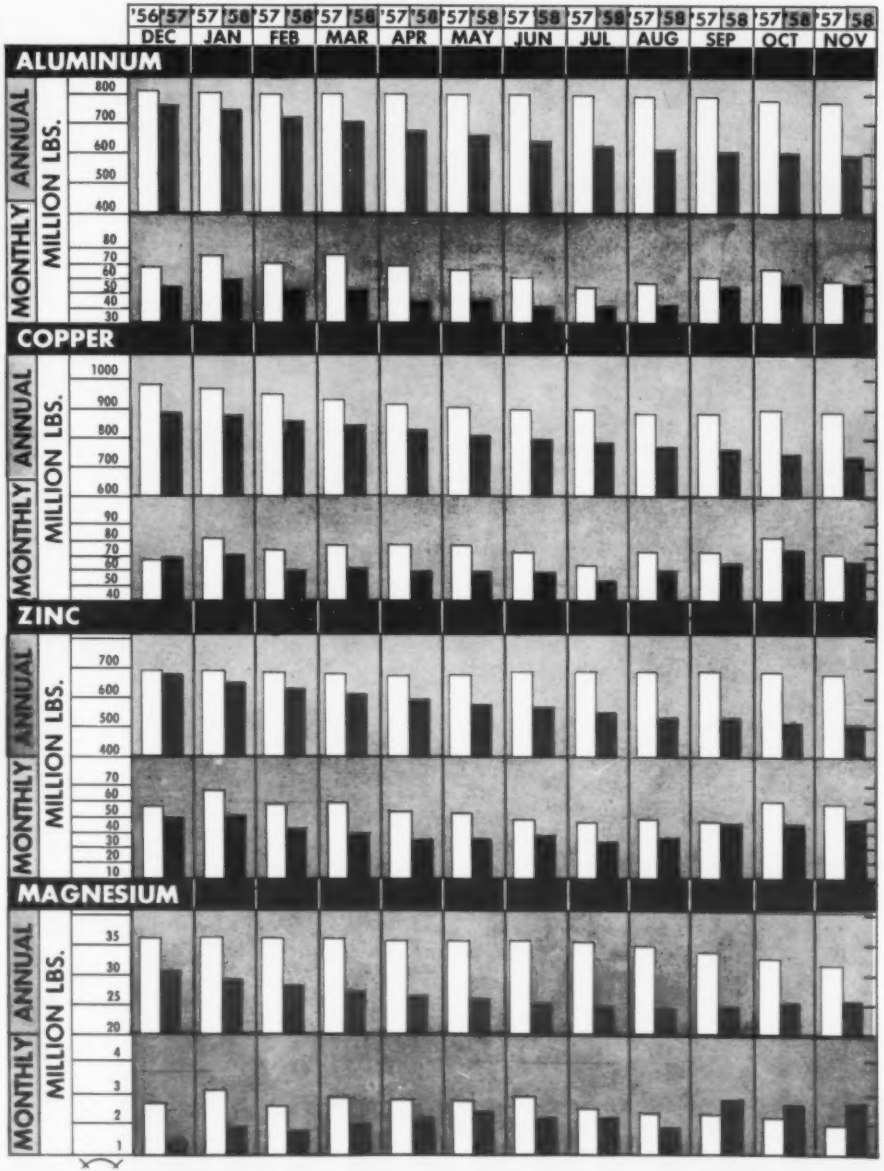
---

a bullfighter with no bull is no worse off than a foundryman without **modern castings.** Use the subscription card on the last page of this issue

how's business . . .

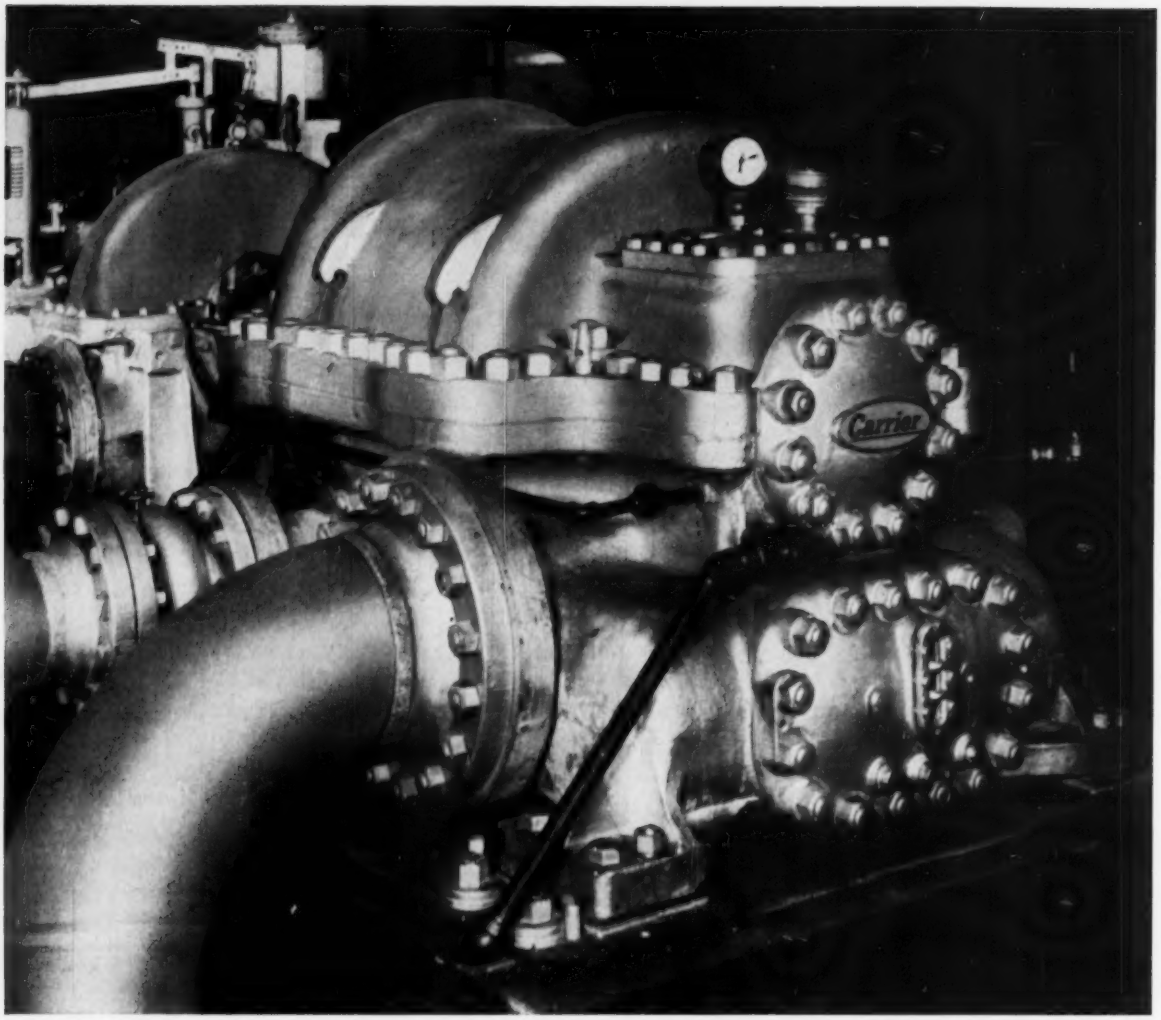
The short and long term trend for metalcastings shipments are presented here in bar chart form from statistics provided by the Bureau of Census, Department of Commerce. By examining the upper chart for each metal, you can see how the weight of castings shipped during a 12 month period has gradually declined since the period Jan. '56 – Dec. '56 (first bar left of each chart). A reversal of this long range trend is levelling off as the result of a rebound from the low level of summer months activity.




'56 '57 '57 '58 '57 '58 '57 '58 '57 '58 '57 '58 '57 '58 '57 '58 '57 '58 '57 '58 '57 '58 '57 '58
DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
ALUMINUM
MONTHLY ANNUAL MILLION LBS.
800 700 600 500 400
80 70 60 50 40 30
COPPER
MONTHLY ANNUAL MILLION LBS.
1000 900 800 700 600
90 80 70 60 50 40
ZINC
MONTHLY ANNUAL MILLION LBS.
700 600 500 400
70 60 50 40 30 20 10
MAGNESIUM
MONTHLY ANNUAL MILLION LBS.
35 30 25 20
4 3 2 1

Each bar in upper chart for each metal represents total shipments for 12 month period ending in year and month indicated. Example: In gray iron chart, last colored bar on right shows 10,340,000 tons shipped during period Dec. '57-Nov. '58 inclusive; adjacent white bar shows 12,907,000 tons for period year earlier, Dec. '56-Nov. '57.

Lower chart for each metal shows total shipments for each month in year indicated. Example: In gray iron chart, last black bar on right shows 958,000 tons shipped in Nov. '58 compared with white bar showing 940,000 tons in Nov. '57.



4½% Nickel plus good casting makes these casings strong and tough at –185°F

Here's how the foundry solved a low temperature problem:

This Carrier #350 Compressor is designed for producing ethylene by low temperature (–185°F) high pressure (600 psi) fractionation.

Under these conditions ordinary cast steel is brittle and could easily fracture. Could the foundry turn out castings which would have high strength and toughness at the low temperatures involved?

They could . . . this way:

They made these three-ton compressor housing castings from 4½% nickel alloy steel; normalized and water quenched them, and finally tempered them. Under this treatment the castings easily exceed these minimum mechanical properties:

Ultimate tensile strength	70,000 psi
Yield strength	40,000 psi
Elongation in 2"	22%
Reduction of area	30%
Charpy keyhole impact (@ –185°F)	15 ft. lb.

Nickel does wonders for cast irons and steels destined for severe service . . . aids development of desired metal structure.

Recommend Nickel Alloys Freely

Nickel is a plentiful and versatile material and you can count on Inco Nickel's Development and Research Division for information to help you in selecting specific materials to use in particular applications.

The INTERNATIONAL NICKEL COMPANY, Inc.
67 Wall Street New York 5, N.Y.

INCO NICKEL

NICKEL ALLOYS PERFORM BETTER LONGER

Presenting a modern castings FORUM for DESIGNERS and BUYERS

modern castings

14 special articles start on page 23

How and why to use metal castings

This Forum for Designers and Buyers may well provide a major break-through in opportunities for castings to better serve industrial needs.

For a 74-page count-down on the benefits to be derived from the use of castings, study closely the 14 carefully prepared technical articles which follow.

Metal castings have long been recognized as the shortest line between raw material and finished product. Product-design engineers and castings buyers should be aware of the many other plus values which contribute to high integrity performance of castings. This Forum tells why castings are best for . . . engineering economy . . . design freedom . . . high productivity . . . and wide selectivity of properties.

The AFS Engineered Castings Show in Chicago, April 13-17, is the market-place where foundrymen will prove how castings are the superior product for solving design problems.

Reading the Forum and seeing the Show are just the prologue. Then a profitable end-product needs the hard work of a closely cooperating triumvirate:

1) Designers . . . with the capacity to envision
2) Buyers . . . the link between
3) Foundrymen . . . with the ability to perform.

Raise the iron curtain of misunderstanding and prejudice that often blocks intelligent communication between these three groups and metal casting can meet almost any challenge!

The GRAY IRON FOUNDERS' SOCIETY

tells DESIGNERS AND BUYERS why and how to use

RICHARD C. MELOY
Marketing Director
Gray Iron Founders' Society, Inc.
Cleveland

GRAY AND DUCTILE IRON Castings

Engineers are beginning to recognize that they have not been giving the consideration to gray and ductile iron castings that they deserve, in the designing of components. As one designer puts it, "Engineering advances are frequently measured in terms of the daring usage of new materials. Finding a new use for an old material can often be even more rewarding."

Purchasing agents, as they build value analysis programs, are learning that iron castings frequently offer important savings in overall manufacturing costs.

Back of this growing recognition are three developments which are taking place within the gray iron foundry industry itself:

1) Economic trends favor gray iron castings. Through mechanization and better cost controls, foundries are doing a more efficient job.

2) Informed foundrymen are providing design assistance to engineers and better pattern service to their customers. Foundries are singularly qualified to render service in these areas and are greatly stepping up their efforts as a result of an industry-wide marketing program. One of many examples of the savings that can result when the foundry and user put their heads together is shown in Fig. 1.

3) More technical information is being made available to engineers regarding the growing family of irons. An important contribution to this educational phase is the new *Gray Iron Castings Handbook*, published by the Gray Iron Founders' Society in 1958. The handbook provides easy reference to data on design right through specifying to machining and finishing the completed castings.

These developments explain what is behind the new look being given castings. The reasons for actually specifying gray iron castings are found in their advantages which can be listed under (A) product superiority due to properties of the material and nature of the casting process, and (B) inherent economies of gray iron castings. Economy is frequently combined with product superiority as is indicated in the discussion of properties.

PROPERTIES

There are dozens of standard specifications of gray and ductile irons, and scores of special irons developed by individual foundries to meet specific needs. In general they have the following properties, although some may rate higher in certain characteristics than others:

1. Damping capacity. The lower strength irons are especially good at damping out vibrations. This helps to explain gray iron's popularity as bases and frames where high speed machinery is used.

2. Wear resistance. Gray iron is outstanding in many ways; examples are bearings, machine tool ways and brake drums.

3. Hardness. Gray irons cover a wide range; as-cast, heat treated or alloyed. A simple spacer plate for an oil pump provided a savings of 88 per cent when converted to gray iron from a steel stamping, and also eliminated manufacturing difficulties.

4. Corrosion resistance. Gray iron is regularly used to handle many corrosive materials. Cast iron pipe purchased by Louis XIV to supply the fountains of Versailles is still in use after 300 years.

5. Stability. Cast iron has an unusual ability to stay where it is put. A good example is a broach holder, Fig. 2, which caused difficulties because of bowing slightly when made of steel; conversion to an iron casting solved the problem.

6. Uniform grain structure is a valuable feature of gray iron. Even in a symmetrical part, machined all over, variation in density of a material or porosity in a casting will affect the performance.

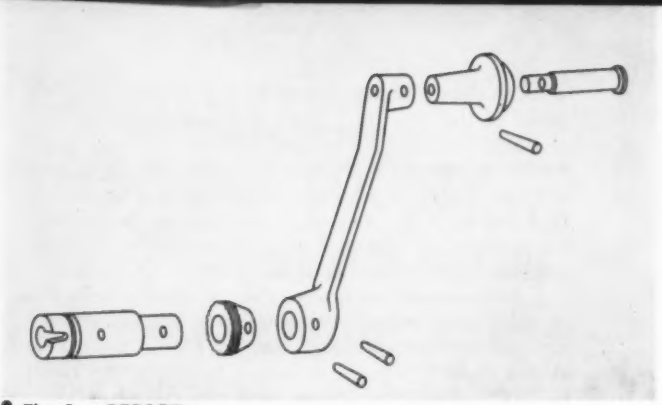


Fig. 1 . . BEFORE
Accounting machine crank consisted of an assembly of eight parts.

Fig. 1 . . AFTER
Shell molded gray iron casting cut cost 78% and improved appearance.

7. Tensile strength. While gray iron is not noted for high tensile strength, it's much better in this regard than many people realize. The standard specifications show different classes of gray iron ranging from 20,000 to 60,000 psi; and with heat treating, gray iron can provide 70,000 to 80,000 psi. Standard ductile irons range from 60,000 to 120,000 psi and also go higher with heat treating. Figure 3 illustrates an application requiring high strength.

8. Compressive strength. Here gray iron is notable. Compressive strength ranges from three to five times the tensile strength. This property is used to advantage in bridge supports. Design Note: If a part can be put under compression rather than tension, it is often possible to design a lighter casting.

9. Lack of notch sensitivity. Gray iron is particularly impervious to notches. Examples are found in cams, gears and other parts which have slotted keyways.

10. High temperature properties. Examples of the satisfactory performance of cast iron at elevated temperatures are found in such commonplace items as cooking utensils, stoves, furnaces and more unusual applications such as sintering bars and most recently, the rocket launcher for the La-Crosse missile.

11. Low temperature—exerts only slight influence on the properties of gray iron. In fact, some irons gradually increase in tensile strength below zero. This explains its satisfactory performance in all kinds of machinery used in polar expeditions and its use in ammonia valves in ice making plants.

12. Impact resistance. Modern gray irons are considerably improved over older types when it comes to toughness. However, if fairly high impact resistance is required, it would be better to specify ductile iron.

13. Non-Magnetic properties. These are obtained by alloying iron. This property is well illustrated by the many iron castings used on the Navy mine sweepers.

14. Thermal conductivity of gray iron is excellent as used in household radiators, in air compressors and air-cooled engines.

15. Rigidity. This is one of the outstanding characteristics of gray iron. The most obvious examples are machine tool bases and electric motor frames. But even in a simple base for a pump and motor, Fig. 4, a gray iron casting improved product performance by eliminating deflection.

16. Fatigue resistance of gray iron is well illustrated by a large diesel crankshaft.

17. Variation of above properties. A composite of properties in the same casting is possible with localized heat treatment. This application is found in lathe bedways, camshafts, gears, etc.

GRAY IRON CASTING DESIGN

The casting process can add to product superiority. Some of these product advantages that follow are due to the casting process, and some are due to the material. More can be done, with less difficulty, with gray iron than is possible with other metals.

Fig. 2 . . Stability of gray iron overcame a distortion problem in the production of this broach holder.

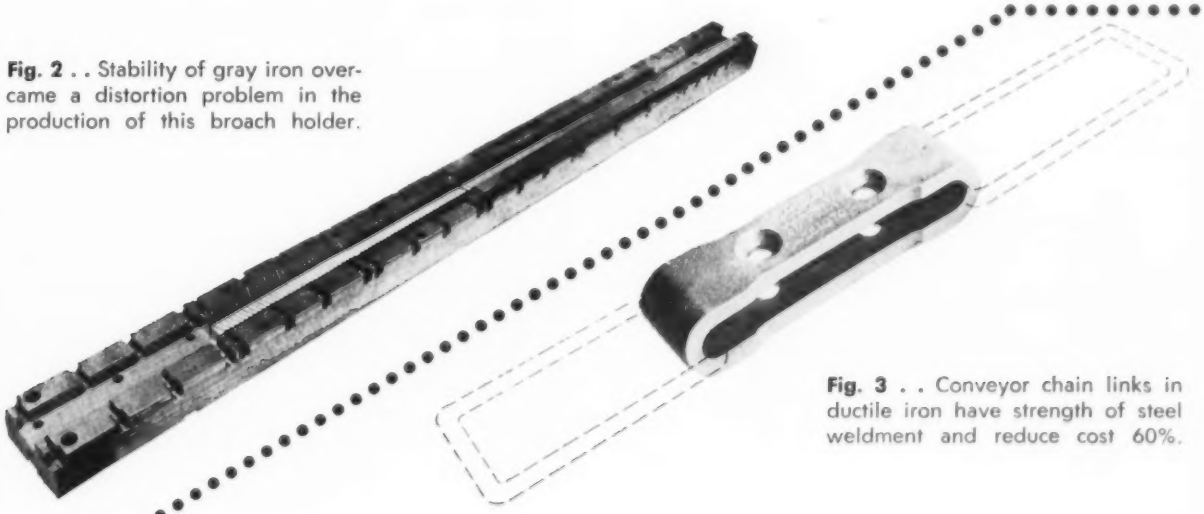


Fig. 3 . . Conveyor chain links in ductile iron have strength of steel weldment and reduce cost 60%.

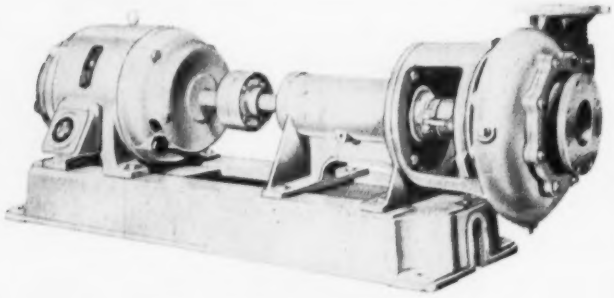


Fig. 4 . . Iron base saved $21.41 and solved vibration and deflection problem.

1. **Weight**—Do you want to add weight as one company did in a portable film cutter? The machine performed more satisfactorily after the case was redesigned to a gray iron casting because it didn't slide around the worktable. This product improvement, plus the resulting cost savings, has meant greatly increased sales.

Or do you want to reduce weight? This is possible in three principal ways: (1) Cutting down on integral parts. (2) Weight can also be reduced by placing metal just where it is needed, tapering where width or thickness is not necessary, coring out where weight can be reduced indirectly by means of cast-material serves no functional purpose. This is done to reduce the weight of crankshafts. Finally, (3), weight can be reduced indirectly by means of casting. Figure 5 illustrates the indirect approach.

2. **Complexity**—Here the advantage of the casting process is probably most obvious. Outstanding examples are found in the intricately cored passages of diesel engine cylinder heads and automobile engines. Del Harder of the Ford Motor Co. has recently stated: "Gray iron foundries have done an outstanding job in producing parts impossible to make by any other process."

3. **Size and section thickness**—Here the rules are wide open when it comes to gray iron; from ounces to more than a hundred tons in one casting. And because of the way gray iron solidifies, section thickness and variations in section thickness do not create the limiting factors of design which is characteristic of some metals. Variations of 4 or 5 to one in the thickness of parts of a single casting are no particular problem to the gray iron foundryman. Greater variations can be handled if necessary.

4. **Dimensional accuracy**—This is usually achieved by machining critical surfaces, but some surfaces are not practical to machine, and by taking advantage of the casting process, sufficient accuracy can often be built-in. Figure 1 is a good illustration of cost saving which is possible by sufficiently accurate molding to eliminate machining.

5. **Integral design**—This feature of the casting process offers many advantages in appearance, cost, assembly, permanent alignment, purchasing, engineering time, etc.

6. **Combination with other metals**—gray iron can be poured into or around other metals which have been set in the mold or built into cores to give the final product specific properties. To take advantage of the wear resistance of gray iron, airplane brake drums have gray iron inserts in formed steel shells.

7. **Appearance and design freedom.** The lack of design limitations inherent in the casting process offer important advantages in appearance. These might be singled out as: (1) the ability to streamline a product or part to give pleasing proportion and line; (2) the rugged feeling of permanence, which is found in an iron casting, is also a definite appearance advantage. The promise that it gives of durability and service-free performance adds to its value; and (3) some designers faced with a perfectly smooth, flat surface are beginning to cross-hatch or otherwise decorated the surface to get away from monotony and give texture to a piece—in a sand casting, texture is a built-in feature.

Fig. 5 . . Cast pump-to-engine coupling shortened entire unit by 12 in.; saved 78 lb in weight; lowered cost about 40%.

ECONOMY

Many of the properties and casting advantages noted above are considerably enhanced by the economic benefits they contribute. However, a couple additional items should be noted:

1. Machining—The American Society of Tool Engineers has estimated that *the metal which is whittled away in chips every year amounts to 15 million tons.* Designing for casting is an obvious way to reduce this waste. It should be noted finally that gray iron is inherently a satisfactory material to machine because of its free machining characteristics.

2. Engineering time—saved in designing a casting is frequently more valuable than the pattern cost. This is a factor generally overlooked, particularly when only one or two of a part is needed. It will pay the designer to get into the casting design habit in terms of greater personal accomplishment.

It will pay a company to get into the casting design habit—particularly the gray iron casting design habit—in increased sales because of better looking, improved products, and in healthier profits due to lower cost production.

The MALLEABLE FOUNDERS' SOCIETY

tells DESIGNERS AND BUYERS why and how to use

HANS J. HEINE /
Technical Director
Malleable Founders' Society
Cleveland

MALLEABLE IRON Castings

Malleable iron castings have not received the attention from designers and potential users which they deserve. Their unusual combination of properties, including excellent toughness, corrosion resistance, machinability and castability, make them suitable for a wide range of uses.

By far the largest tonnage of malleable castings normally is consumed by the automotive industry. The railroad, agricultural implement, electrical line hardware, pipe fittings, and detachable chain industries, and most other basic industries, use standard and pearlitic malleable castings.

According to figures released by the Department of Commerce, there are about 125 malleable iron foundries in the United States. Their estimated annual production capacity is 1,250,000 tons.

There are two major types of malleable iron. Most important from the standpoint of production volume and use is standard (American) malleable iron, which has a ferritic matrix. Pearlitic malleable, which as the name implies, has a pearlitic matrix, is being produced in ever-increasing quantities.

Table I indicates the wide range of strengths available in the two types of malleable iron.

The manufacture of malleable iron castings is fundamentally a two-step process. First is the manufacture of white iron castings; these are then converted, through a controlled heat-treating process, into the desired end product.

Subsequent to annealing, castings are cleaned and finished. Malleable iron's ductility permits straightening or coining to close dimensional tolerances, thus reducing the necessary machining allowances substantially.

Malleable iron is commercially produced to a wide range of chemical compositions depending upon the melting procedure employed, availability of raw materials, section size of the castings produced and heat-treating practices. The range is indicated in Table II.

TABLE I – TENSILE PROPERTIES
A.S.T.M. MINIMUM SPECIFICATIONS

Standard and Pearlitic Malleable Irons			
Designation	Tensile Strength psi	Yield Strength psi	Elongation % in 2 in.
Standard			
35018	53,000	35,000	18
32510	50,000	32,500	10
Pearlitic			
45010	65,000	45,000	10
45007	68,000	45,000	7
48004	70,000	48,000	4
50007	75,000	50,000	7
53004	80,000	53,000	4
60003	80,000	60,000	3
80002	100,000	80,000	2

Strengths up to 135,000 psi tensile and 110,000 psi yield are produced commercially under individual producers' specifications.

TYPICAL BRINELL HARDNESS NO. RANGES
PEARLITIC MALLEABLE IRONS

Designation	45010	45007	48004	50007	53004	60003	80002
Bhn	163-207	163-217	163-228	179-228	197-241	197-255	241-269

TABLE II – TYPICAL COMPOSITION RANGE OF MALLEABLE IRON

	Malleable Iron (white iron)* %
Carbon	2.00-2.65
Silicon	1.40-090
Manganese	0.25-0.55
Phosphorus	Less than 0.18
Sulfur	0.05-0.18

*The chemical composition of malleable iron is always expressed in terms of white-iron analysis.

Load binder castings illustrate a design that utilizes the ductility of malleable castings. Shifting loads induce stresses but these fittings will hold. This is also an illustration of the diversity of applications where malleable can serve.

Structurally, malleable iron castings consist essentially of carbon-free iron (ferrite) and uniformly dispersed nodules of temper carbon accounts for the desirable mechanical properties of malleable iron. In pearlitic malleable the matrix is essentially pearlitic, resembling that of a medium-carbon steel.

Important attributes of malleable iron, showing a unique combination for a cast metal, can be summarized as follows:

1. Malleable materials can be produced with a high yield strength, which is the static mechanical property upon which most mechanical design is based.
2. Malleable and pearlitic malleable have a high ratio of yield strength to tensile strength. This means that the engineer can design to high applied strength values in service for materials of construction, concomitant with good machinability and low production cost for the final part.
3. Pearlitic malleable can be produced to a wide range of mechanical properties through carefully controlled heat-treatments.
4. Malleable irons have a high modulus of elasticity and a low coefficient of thermal expansion, compared with the non-ferrous metals.
5. Malleable and pearlitic malleable do not exhibit a definite nil ductility (impact transition) temperature.
6. Compared with steel, malleable and pearlitic malleable have considerably better damping capacity, which makes operation of moving components less prone to noise because of resonant vibration.
7. Pearlitic malleable has good wear resistance and excellent capability for selective hardening by flame, induction or the carbonitriding process.
8. Pearlitic malleable will take a high quality finish. Honed surfaces with two to three microinch finish at hardness values of 197 to 207 have been reported.
9. The uniformity of properties throughout all section thicknesses is excellent, particularly in oil-quenched and tempered pearlitic malleable.
10. All malleable metals are completely free from casting stresses as a result of high temperature heat treatment.
11. Pearlitic malleable iron provides the properties of medium to high carbon steel coupled with excellent machinability.

With respect to mechanical properties, minimum specification values are generally exceeded by a comfortable margin in the better controlled malleable foundries.

Brinell hardness of standard malleable irons varies from about 110 to 145. Pearlitic malleable and alloyed grades have higher values, ranging usually between 160 and 285 Bhn. Both hardness and tensile strength increase with combined carbon content.

Since the final properties of malleable iron castings are the result of thermal treatments, the section thickness has no appreciable effect on strength. Therefore, mechanical properties will be essentially the same throughout the entire section.

Studies of the behavior of standard malleable iron at both high and lower temperatures demonstrate, in general, that this material is well suited to applications in a temperature range from −60 to 1200 degrees F.

Low temperature investigations have been concerned primarily with impact resistance and notch sensitivity; high temperature studies have focused principally on tensile strength, yield point, elongation, stress rupture and creep.

Results of research sponsored by the Malleable Founders' Society have indicated a high level of elevated temperature performance, equal or superior to other ferritic materials for which data are available, particularly at 800 degrees F. The strength at 1000 degrees F is adequate for many applications; strength is retained even at 1200 degrees F. No evidence was found in any of the investigations of changes in structure or performance during the test periods which extended from 1 to over 2000 hours.

Many structural parts require high surface hardness backed up by a strong, tough core. In steel components this can be accomplished by carburizing or nitriding after machining, followed by a suitable heat-treatment. In pearlitic malleable iron the combined carbon content is adequate for production of high surface hardnesses through quenching after either in-

Pearlitic universal yoke replaced a steel forging. Shown before and after machining.

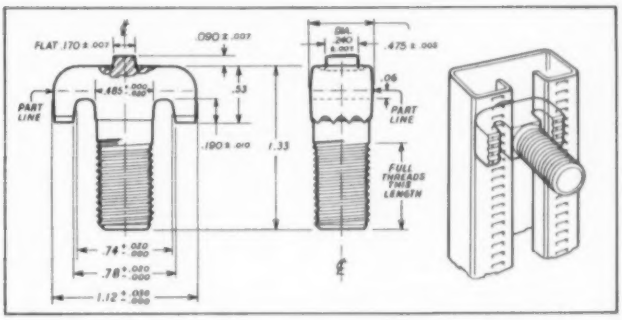
Steel weldments and the malleable castings that replaced them. The weldments are shown at top. At the left is a male-female hinge, at the right, a bolster mount. Change reduced cost and weight.

duction or flame heating. Many pearlitic parts are preferentially hardened on wearing surfaces.

The design freedom offered by the castings process is being applied successfully in many highly critical mechanisms. The malleable industry produces parts ranging in size from a fraction of an ounce to several hundred pounds, such as complicated automotive transmission parts, intricate valve bodies and multipart assemblies which cannot be economically forged or welded. New applications are constantly being developed as the result of a continually expanding foundry technology. This in turn results in savings and an improved product for the customer.

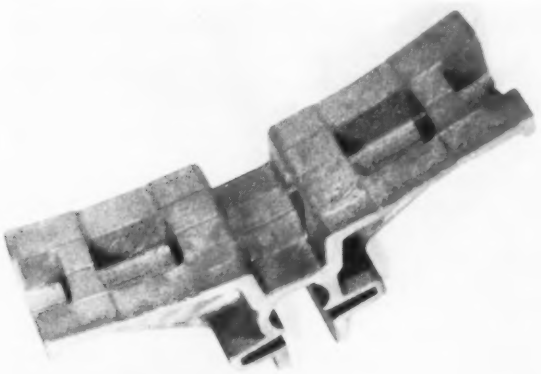
BIBLIOGRAPHY

(1) *American Malleable Iron—A Handbook*, Malleable Founders' Society, Cleveland.
(2) Malleable Founders' Society, unpublished data.
(3) *Malleable Iron Facts*, Malleable Founders' Society.
(4) *Pearlitic Malleable Iron*, Albion Malleable Iron Company.
(5) CAST METALS HANDBOOK, American Foundrymen's Society.
(6) Konstrukteur und Giesser, Verein Deutscher Giessereifachleute, Dusseldorf.
(7) Private communication from Centre Technique de Fonderie, Paris.
(8) Information developed by MFS Handbook Committee.



Pearlitic malleable bolt holds 4-ton steel channel frame. 7/16-in. bolt has tensile of 90-100,000 psi.

Brake beam component demonstrates how malleable castability enables designer to obtain optimum design.



Second malleable component brake beam emphasizes importance of metal to U.S. railroad industry.

The STEEL FOUNDERS' SOCIETY OF AMERICA

tells DESIGNERS AND BUYERS why and how to use

STEEL Castings

C. W. Briggs / *Technical & Research Director*

G. K. Dreher / *Market Development Director Steel Founders' Society of America Cleveland*

When designers are seeking the ultimate . . . in strength . . . in modulus of elasticity . . . in high and low temperature properties . . . in endurance limit . . . it will probably be steel that meets their requirements. When buyers are faced with selecting the steel fabricating technique that offers . . . unlimited size restrictions . . . rapid tooling at minimum investment . . . design freedom . . . most favorable final cost . . . their choice will most likely be casting.

Steel castings function as the tough muscles of the heavy-duty, hard working equipment used by railroads, road builders, miners, farmers and many others. For proof examine the pie chart reproduced here showing the percentage distibution of steel castings by industries served. What this means in tons can be readily calculated from the fact that total shipments of steel castings amounted to 1,800,000 tons in 1957.

WHY USE STEEL CASTINGS?

Here are 12 *ways steel castings aid in successful product design:*

1. Design freedom . . . permits functionally efficient designs with optimum strength—weight-size-shape balance through mathematical and strain analysis.

2. Industrial design . . . gives desirable shape and contour with eye appeal.

3. Cast-weld construction . . . improves cost factor by dividing large or complex structures into two or more simplified steel castings and welding them together for final assembly.

4. Composite fabrication . . . avoids excessive costs of machining and assembly by welding steel castings to rolled, formed, forged or extruded parts.

5. Beneficial grain structure . . . has uniform strength in all directions because equiaxed crystals are inherent to steel castings.

6. Wide selection of properties . . . is possible through large selection of alloys and variety of heat treatments.

7. Dimensional uniformity . . . permits steel castings to be made in production quantities to close tolerances on critical dimensions for functional use without machining.

8. Shock resistance . . . steel castings can be designed to absorb compression, tension, torsion and thermal shock to a greater degree than wrought products.

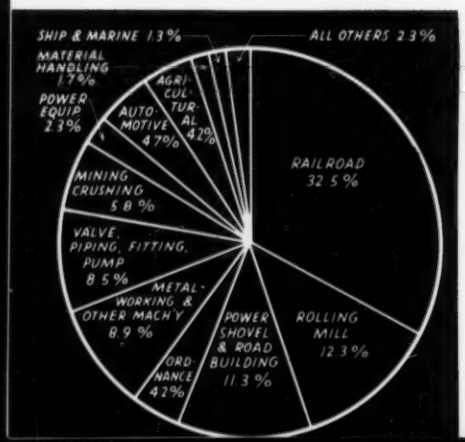
9. Service stability . . . can be designed into steel castings so they resist deflection and deformation over long periods of time involving millions of stress cycles.

10. Optimum fatigue life . . . comes from notch resistance and multi-directional endurance properties.

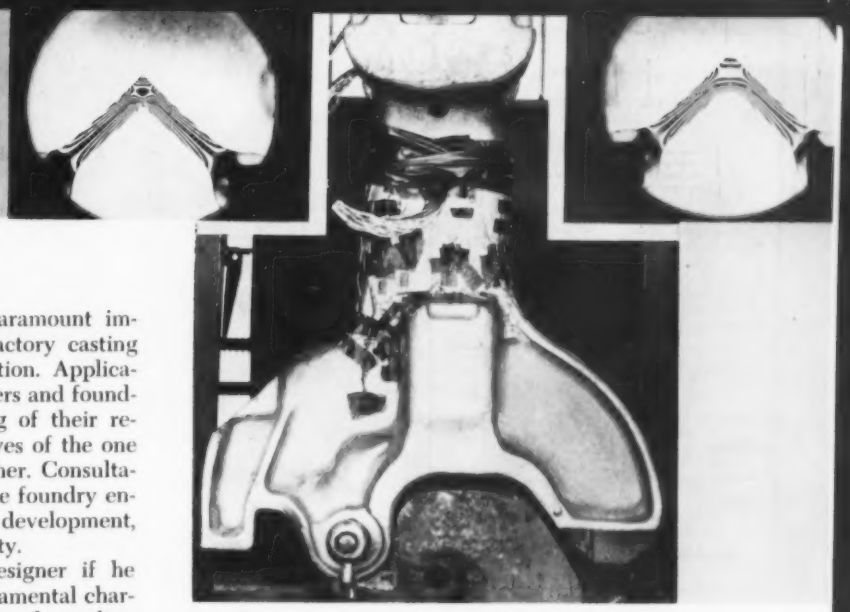
11. Process freedom . . . allows steel castings to be further improved by forging, coining, hot and cold pressing, brazing, welding, metal-spraying and hard surfacing.

12. Engineering economy . . . results from steel castings providing components at lowest cost consistent with performance requirements and minimum maintenance.

Where steel castings are used



Strain gage analysis of coupler disclosed stress concentration which was eliminated by lighter and stronger redesigned casting.



DESIGN FUNDAMENTALS

Correct steel casting design is of paramount importance as it is responsible for satisfactory casting service and economical casting production. Applications are constantly expanding as designers and foundrymen approach a better understanding of their respective problems, adjusting the objectives of the one to the facilities and technique of the other. Consultation between the design engineer and the foundry engineer, while the design is in process of development, will improve casting quality and castability.

It would be most helpful to the designer if he would memorize the following four fundamental characteristics concerning steel as it cools from the molten condition to room temperature:

1. Low fluidity. Liquid steel, in comparison with other common metals, has lower fluidity; therefore the casting design should not call for sections so thin as to cause losses from failure to reproduce the mold contour or to greatly increase manufacturing costs owing to the necessity of having to use excessively high pouring temperatures.

2. High shrinkage. The volumetric contraction that takes place when steel transforms from the liquid to the solid state is comparitively high. This means that much thought must be given to the casting design so that the contraction is compensated by a supply of liquid steel.

3. Low strength at 2700 F. Steel, in common with other metals, possesses very low strength and ductility at temperatures immediately below the solidification temperature; hence, careful attention must be given to design features from the standpoint of reducing possible stresses acting upon the castings at this time.

4. High cooling stresses. A steel casting section solidifies from the mold-metal interface toward the center of the section with the total volumetric contraction occurring at the last point of solidification. The rate of solidification is roughly similar regardless of the section thickness. Thus, heavier sections take longer to solidify than lighter sections. Thinner sections which are integrally connected to heavier sections will completely solidify and start contracting while heavier sections are still solidifying.

The temperature gradients so established will result in different rates of contraction in the different sections after they become solid, thus producing internal stresses in the casting.

STRESS ANALYSIS

The "L" section is the most common encountered in cast shapes. So proper design is a must. All designers appreciate the stress-raising effects of sharp corners. A current research project of the Steel Founders' Society of America is studying corner design. Photo-elastic techniques demonstrate the undesirable stress buildup at sharp corners and how proper filleting of radii dissipates these concentrations.

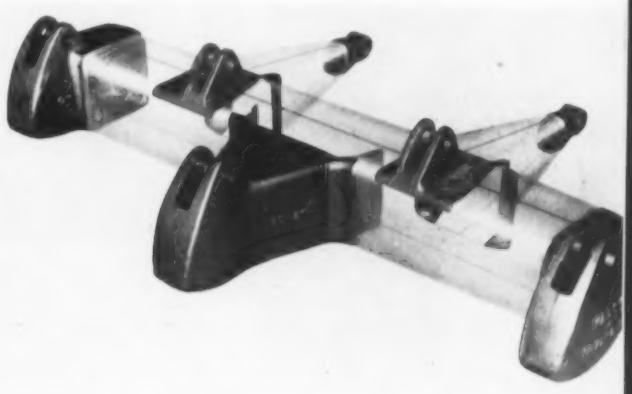
More and more steel foundrymen are working closely with design engineers in redesigning parts by using stress analysis. Brittle lacquer and strain gages reveal stress distribution patterns on static-loaded castings. Using this as a guide the optimum design can be determined. Such a strain gage analysis is shown above being made on a train coupler loaded in static tension. Results: lighter and stronger castings with safety factor reduced from two or three down to one.

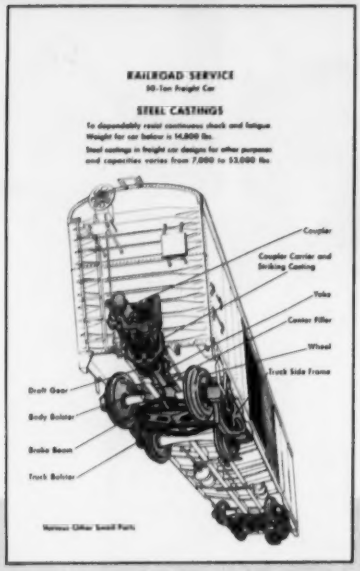
In the narrow confines of this article it is impossible to adequately cover the subject of steel casting design. A 34-page booklet, "Fundamentals of Steel Castings Design," has been prepared by S.F.S.A. and is available on request.

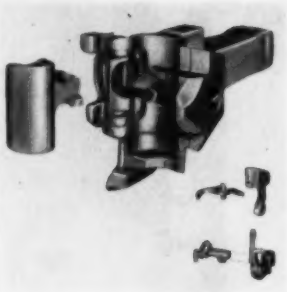
PHYSICAL PROPERTIES

Many designers select their materials on the basis of certain critical physical properties such as tensile strength. The table classifies the various types of steel in this manner. The designer can select the important property or properties and value needed, then locate the appropriate specs. Table also identifies outstanding characteristics of the steels.

Cast-weld construction of rock-ripper frame lowered cost and improved design.







CAST-WELD CONSTRUCTION

Because cast steel is readily welded, a whole new field of opportunity to trim costs lies in "cast-weld construction." Frequently metal components are either too large or too complex to be made as a single casting. This problem can be solved by breaking the design down to several castings and welding them together into the final assembly. In addition to benefits of lower cost and reduced weight usually accruing from this practice, cast-weld construction often results in faster production.

General Engineering
(Classified According to

STRUCTURAL GRADES—CARBON STEELS

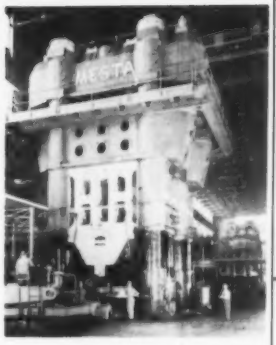
Tensile Strength, Psi	60,000	65,000	70,000	80,000	85,000	100,000
Indicated Application	Low electric resistivity. Desirable magnetic properties, carburizing and case hardening grades. Weldability.	Excellent weldability. Medium strength with good machinability and high ductility.		High strength carbon steels with good machinability, toughness and excellent fatigue resistance.		Wear resistance hardness.
Current Specifications	ASTM: A27-55 U60 – 30 60 – 30 ASTM: A216-53T WCA AAR: M201-53 Grade AU Grade AA Federal: QQ-S-681b Class 1 Navy: 49S1 Class B & D ABS Class 1, Hull	ASTM: A27-55 65 – 30 65 – 35 SAE: Automotive 0030 Federal: QQ-S-681b Class 2 Lloyds Class A ASTM: A352-55T LCB	ASTM: A27-55 70 – 36 ASTM: A95-44 70 – 36 ASTM: A216-53T WCB AAR: M201-53 Grade B Military MIL-5-15083 A-70 ABS-Class 2	SAE: Automotive 080 Federal: QQ-S-681b Class 3 Navy: 49S1 Class A	SAE: Automotive 0050	SAE: Automotive 0050
A Typical Specification for the Tensile Grade with Requirements Listed Below	ASTM A27-55 Class 60 - 30	ASTM A27-55 Class 65 - 35	AAR: M201-53 Grade B	Federal QQ-S-681b Class 3	SAE: Automotive Class 0050	SAE: Automotive Class 0050

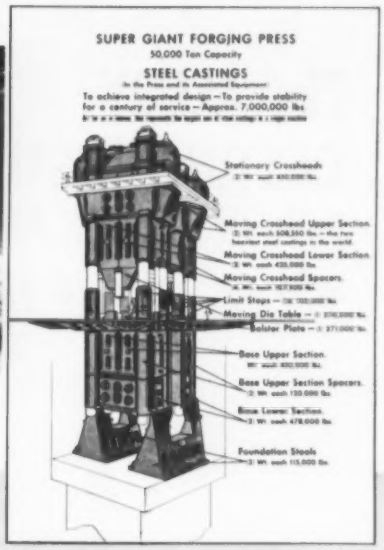
Values listed directly below are those normally expected in the production of steel
The values listed below are only for general information and

Tensile Strength, Psi	60,000	65,000	70,000	80,000	85,000	100,000
Yield Point, Psi	30,000	35,000	38,000	45,000	50,000	70,000
Elongation in 2 In., %	30	30	28	26	24	20
Reduction of Area, %	50	53	50	43	40	43
Brinell Hardness No.	120	130	140	160	175	215
Charpy Impact** at 70 F ft-lb	35	35	30	35	30	25
Charpy Impact** at–50 F ft-lb	8	12	10	12	12	15
Endurance Limit, Psi	25,000	28,000	31,000	35,000	38,000	47,000
Modulus of Elasticity	30 million psi	30 million psi	30 million psi	30 million psi	30 million psi	30 million psi
Machinability Rating‖	55	60	65	70	70	65
Type of Heat Treatment	Annealed	Normalized	Normalized	Normalized and tempered	Normalized and tempered	Quenched and tempered

* *Below 8% total alloy content.*
** *Keyhole notch.*
‡ *Machinability rating by Research Committee on Cutting Fluids—"Metal Progress," Oct. 1943, pp. 622-624. Cold rolled screw stock equals 100.*
‖ *Test values obtained in accordance with ASTM testing procedures.*
‡ *SAE hardness requirement.*

An outstanding example of this composite fabrication technique won first prize in the S.F.S.A. 3d Product Development contest. Pictured on p. 31 is the winning rock ripper frame designed by P. H. Edwards, Contract Engineering, Fort Worth, Texas. Eleven castings were welded to steel plates in making this rugged ripper used to break up all types of earth formations for road building. This new design netted a cost reduction of 50 per cent and weight reduction of 25 per cent over previous fabrication method.





Types of Steel Castings

Tensile Strengths)

ENGINEERING GRADES – LOW ALLOY STEELS*

70,000	80,000	90,000	100,000	110,000	120,000	150,000	175,000	200,000	250,000
Excellent weldability. Medium strength with high toughness and good machinability.		Certain steels of these classes have excellent high temp properties and deep hardening properties. Toughness.		High resistance to impact Excellent low temp properties for certain steels. Deep hardening. Excellent combination of strength and toughness.		Deep hardening. High strength. Wear resistance. Fatigue resistance	High strength. Wear resistance. High hardness. High fatigue resistance.		Wear Resistant Cast to Size Parts for Abrasive Application
ASTM: A217-55 WC 1 WC 2 WC 3 ASTM: A352-557 LC1, LC2 LC3	ASTM: A148-55 80 – 40 80 – 50 ASTM: A217-46T WC 4 SAE: Automotive 080 Federal: QQ-S-681b 4A1	ASTM. A148-55 90 – 60 ASTM: A217-55 C 5 SAE: Automotive 090 Federal: QQ-S-681b 4A2, 4B1, 4B2, 4C1 AAR: M201-47 Grade C Military MIL-S-15083 A – 90	ASTM: A157-44 C 11 Federal: QQ-S-681b 4B3	ASTM: A148-55 105 – 85 SAE: Automotive 0105 Federal: QQ-S-681b 4C2	ASTM: A148-55 120 – 100 SAE: Automotive 0120 Federal: QQ-S-681b 4C3	ASTM: A148-55 150 – 125 SAE: Automotive 0150 Federal: QQ-S-681b 4C4	ASTM: A148-55 175 – 145 SAE: Automotive 0175	None specified	None specified
ASTM A217-55 WC4	ASTM A148-55 Class 80-50	ASTM A148-55 Class 90 - 60	Federal QQ-S-681b Class 4B3	ASTM A148-55 Class105-85	ASTM A148-46T Class120-100	ASTM A148-55 Class150-125	ASTM A148-55 Class175-145	None specified	None specified

castings for the tensile strength values given in the upper portion of the chart.§§ are not to be used as design or specification limit values.

70,000	80,000	90,000	100,000	110,000	120,000	150,000	175,000	200,000	250,000
42,000	50,000	60,000	65,000	85,000	97,000	130,000	148,000	175,000	190,000
28	27	24	21	18	16	12	8	5	5
55	50	50	46	42	38	25	15	11	5
140	160	190	215	235	260	325	380	420	475+
35	30	26	22	28	24	18	10	–	–
15	15	17	15	22	18	15	6	–	–
33,000	38,000	41,000	45,000	49,000	55,000	65,000	77,000	85,000	–
30 million psi	30 million psi	30 million psi	30 millio npsi	30 million psi	30 million psi	30 million psi	30 million psi	30 million psi	30 million psi
65	70	70	65	60	50	30	–	–	–
Normalized and tempered	Normalized and tempered	Normalized and tempered	Normalized and tempered	Quenched and tempered	Quenched and tempered	Quenched and tempered	Quenched and tempered	Quenched and tempered	Quenched and tempered

The ALLOY CASTING INSTITUTE *tells DESIGNERS AND BUYERS why and how to use*

HIGH ALLOY Castings

ERNEST A. SCHOEFER /
Executive Vice-President
Alloy Casting Institute
New York

Stainless steels are being increasingly applied in the cast form for the solution of many design problems. Not only is it possible to obtain castings in alloy types comparable to all the familiar wrought grades, but many additional compositions with especially attractive properties are produced regularly. This is particularly true for the cast heat resistant alloys, which are specifically designed for high temperature service.

In general, the cast corrosion resistant alloys have about the same degree of corrosion resistance as the equivalent wrought stainless types. A cast design will often give better performance than a wrought design; castings offer design flexibility which permits the designer to eliminate cracks and crevices that might cause accelerated attack by differential aeration or concentration of solutions.

Cast designs are also advantageous for high temperature applications because the cast structure is inherently more rigid than directionally-oriented wrought structures. Also, cast heat resistant alloys are stronger than corresponding wrought types at elevated temperatures. The factors that make an alloy strong at high temperatures are the same as those that make the alloy difficult to roll or forge; thus, around 1700 F the type HT cast alloy has about double the strength of the comparable wrought alloy type 330.

APPLICATIONS

The corrosion resistant cast high alloys play a highly important role in the chemical process industries; equipment utilizing high alloy castings include pumps, valves, fittings, mixers and the like. In the chemical industry the cast high alloys are used to resist nitric, sulfuric, phosphoric and most organic acids as well as many neutral and alkaline salt solutions. Many other process industries are large users of stainless castings, including the pulp and paper industry, soap-making, bleaching and dyeing operations in the textile industry, petroleum refining, petrochemical industry, food and beverage processing industries, the manufacture of plastics, pharmaceuticals and in atomic energy processing.

Heat resistant cast high alloys have a similarly wide range of application. Interestingly, most of these castings are used in equipment for the heat treatment of metals. Typical applications include furnace parts, muffles, trays, quenching fixtures, chain and containers. The oil refining and power generating industries utilize heat resistant castings for supports, chutes, return bends and related equipment. In the cement industry kiln ends and other critical parts are made of high alloy castings.

PURCHASING TIPS

Buyers and designers should not lose sight of the advantages of specifying the standard cast compositions available from the industry. In this connection, designers and buyers are urged to utilize Alloy Casting Institute data sheets on high alloy castings, **and** *to consult with a qualified high alloy foundry* **before** *the design is frozen.*

The following rules are of the utmost importance in purchasing high alloy castings:

1. **Use Cast Metal Specs . . .** While most of the corrosion resistant cast alloy grades have corresponding wrought counterparts, the chemical composition ranges for the cast and wrought alloys are different. For this reason, buyers should use cast alloy designations (ACI) rather than wrought alloy designations (AISI) for proper identification of castings. By so doing, it may be possible to make a much more economical choice of casting materials. This is especially true among the heat resistant alloys, since there are many more cast alloys than wrought alloys available for high temperature service.

2. **Give The Foundry Complete Information On Design Requirements And Expected Service Conditions . . .** Essential information that must be furnished to the high alloy foundry includes the following: Expected temperature of operations; loading conditions; atmospheres; dimensions; unusual or special conditions; exact composition of corrosive medium; working pressures; nature of temperatures—steady or cycling; codes and specifications—local, federal, military, A.E.C.; inspection and testing—x-ray, hydraulic or air, etc.; additional fabrication—welding or machining. This information should be accompanied by detailed drawings showing allowable finish and dimensional tolerances on cast surfaces.

3. **Quality Castings Demand Good Pattern Equipment . . .** Cheap wooden patterns are usually "penny wise and pound foolish". The foundry should not be required to use

TABLE 1—Properties of High Alloy Castings

Group	ACI Designation	AISI *	Nominal Composition—% Cr	Ni	C	Other	Mechanical Characteristics	Fabricating Characteristics
I	CA-15	410	12	–	0.12	–	Strong, fair ductility, low impact strength. CA and CD grades hardenable.	Weldable, but preweld heating at 400-600F required. Postweld heat treat to restore mechanical properties. All grades can be machined satisfactorily.
Straight Chromium	CA-40	420	12	–	0.30	–		
	CB-30	431	20	1	0.25	–		
	CC-50	446	28	2	0.45	–		
	CD-4MCu	–	28	5	0.03	Mo-Cu		
	HA	–	9	–	0.15	Mo	HA strong up to 1100F. HC and HD low stress applications to 2000F.	
	HC	446	28	2	0.45	–		
	HD	327	28	5	0.40	–		
II	CE-30	–	29	9	0.25	–	Strong, good ductility and impact strength at room and subzero temp. Non-hardenable. Tensile: 70-95,000 psi Yield: 35-50,000 psi Elongation: 20-60%	Weldable, no preweld heating required. Postweld heat treatment necessary to restore corrosion resistant properties of "C" grades except for types CE-30, CF-4, CF-4M and CF-8C. All grades can be machined satisfactorily, but surface work-hardens rapidly. Type CF-16F has improved machinability.
Chromium-Nickel	CF-4	304L	19	10	0.03	–		
	CF-4M	316L	19	11	0.03	Mo		
	CF-8	304	19	9	0.07	–		
	CF-8M	316	19	10	0.07	Mo		
	CF-8C	347	19	10	0.07	Cb		
	CF-12M	316	19	10	0.11	Mo		
	CF-16F	303	19	9	0.15	Se		
	CF-20	302	19	9	0.18	–		
	CG-8M	317	20	11	0.07	Mo		
	CH-20	309	24	13	0.18	–		
	CK-20	310	25	20	0.18	–		
	HE	–	28	10	0.35	–	Good for high stress applications at elevated temp. Not as good as Group III for thermal fatigue.	
	HF	302B	21	10	0.30	–		
	HH	309	25	12	0.30	–		
	HI	–	28	15	0.30	–		
	HK	310	26	20	0.35	–		
	HL	–	30	20	0.35	–		
III	CN-7M	–	20	29	0.06	Mo-Cu	Similar to Group II grades.	Weldable. Type CN-7M only needs 400F heating before weld and postweld heat treatment to restore corrosion resistance. All grades machinable similar to Group II.
	HN	–	20	25	0.35	–		
Nickel-Chromium	HT	330	16	35	0.50	–	Good for high stress applications involving cyclic heating and thermal shock.	
	HU	–	19	39	0.50	–		
	HW	–	12	60	0.55	–		
	HX	–	17	67	0.55	–		

*Type numbers shown for identification of corresponding wrought grades only. Castings should be ordered under their cast alloy designations.

Note: Most of the standard grades listed are covered by ASTM Specifications A296-55 and A297-55.

The Alloy Casting Institute, association of high alloy foundries, defines two principal groups: "Corrosion resistant" grades generally used to resist corosive attack at temperatures below 1200 F; and "heat resistant" grades used where the metal temperature is above 1200 F. These alloys are covered by a recognized system of nomenclature, established by the ACI, and adopted by the American Society for Testing Materials in its standard specifications. Designations with the initial letter "C" represent the corrosion resistant types, whereas the heat resistant grades have the initial letter "H".

The second letter shows the nominal chromium-nickel type; the nickel content increasing in amount from "A" to "X". Numerals following the letters indicate the *maximum* carbon content of the corrosion resistant alloys. If special elements are included in a composition they are indicated by the addition of a letter to the symbol. Thus, "CF-8M" is an alloy for corrosion resistant service, of the molybdenum-containing 19% Cr-9% Ni type with a maximum carbon content of 0.08 per cent.

Detailed information on each of the alloy types most frequently specified is available on data sheets published by the Alloy Casting Institute. A summary of the general characteristics of these grades is given in the accompanying table. Many grades not shown in the table, including a number of abrasion resistant types, are cast for specific user requirements.

patterns originally made for the production of the same part in another metal. Obviously, shrinkage allowances as well as other production considerations will be quite different. The consumer should be guided by the foundry's recommendation concerning pattern equipment, which is always made in the interest of producing a better casting at lowest cost.

THREE ALLOY GROUPS

In considering the available cast high alloys for either corrosion resistant or heat resistant service, it is convenient to divide them into three groups:

I. "Straight-chromium" alloys: In this group, the CA grades are hardenable by heat treatment; these alloys have good resistance to oxidation and erosion. As the chromium content is increased, the alloys are no longer hardenable. The CB grades are less ductile than the CA grades; but the corrosion resistance of the CB alloy is considerably better than the CA types. CB alloy is also used for some heat resistant applications. The type CC alloys have good resistance to many corrosive agents.

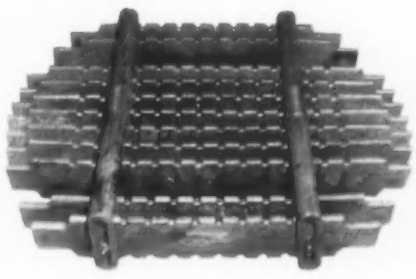
The cast corrosion resistant alloys of Group I will resist ordinary air atmosphere, food products, oxidizing salts and acids as well as ordinary water. The Group I heat resistant alloys (Types HA, HC and HD) are used chiefly for resistance to oxidation at elevated temperatures. The HA alloys, like the CA grades, are hardenable by heat treatment. The HC and HD alloys have good resistance to many corrosive agents and are especially resistant to oxidizing gases containing sulfur at elevated temperatures.

II. Chromium-nickel alloys: Group II includes corrosion re-

Continued on page 134

Fractionating tower is typical of applications in chemical industry.

Heat treating fixture is assembled from individually cast "leaves".



The NONFERROUS FOUNDERS' SOCIETY

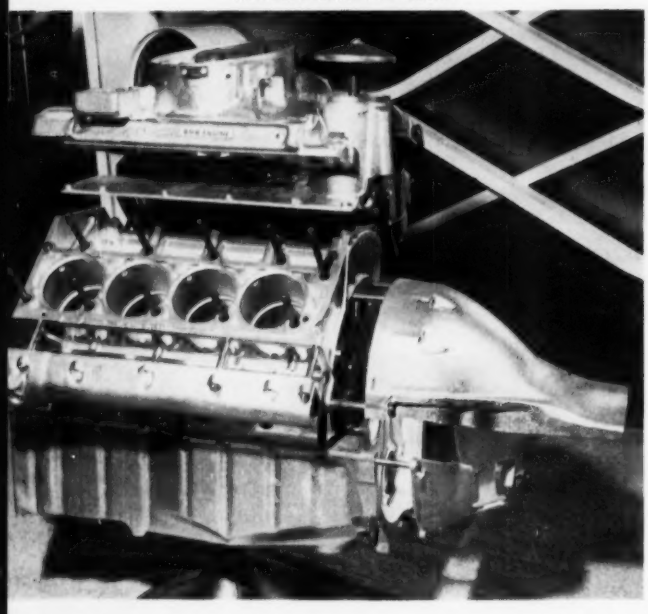
tells DESIGNERS AND BUYERS why and how to use

NONFERROUS Castings

HERBERT F. SCOBIE /
Executive Secretary
Nonferrous Founders' Society
Evanston, Ill.

Like all foundries, nonferrous shops put metal where it is most effective mechanically, at the most reasonable cost, and with maximum streamlining and eye appeal. The nonferrous castings industry is notable, however, for the wide variety of alloys it casts with their tremendous range of properties which meet a broad scale of requirements set by designers and users.

Aluminum auto engine block may revolutionize nonferrous market. This is V-8 engine of German BMW.
REYNOLDS METALS CO. PHOTO



Consisting of some 3000 shops and departments located in every state in the union, the industry is close to consumers everywhere. Some shops specialize in certain alloys or processes or in high production while others are experts in short orders and frequently a considerable number of alloys.

Thus, the casting consumer finds, usually within reasonable transportation distance, one or more producers of nonferrous castings to meet every need he has. In addition, a number of producers are prepared to show how nonferrous castings apply in many cases not previously considered by the user.

Here are some of the factors that enable consumers to make the most of the nonferrous castings industry.

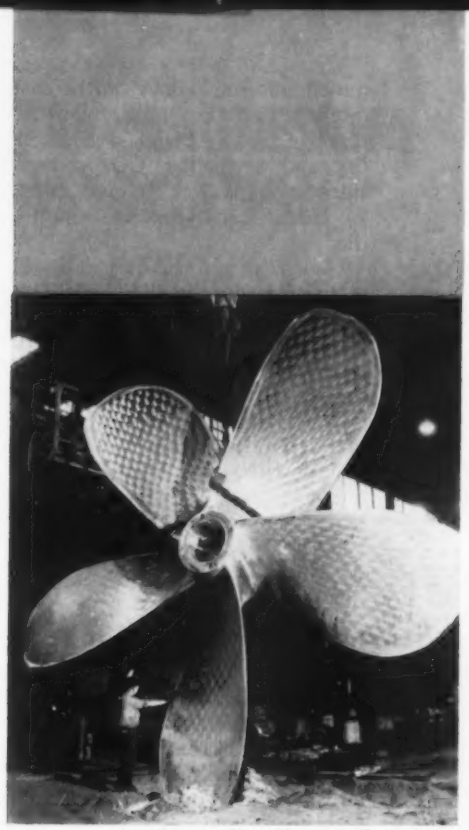
VARIETY OF ALLOYS

The five most common nonferrous casting alloys are aluminum-base, copper-base, magnesium-base, nickel-base and zinc-base.

Aluminum-base . . . The more than 100 aluminum-base alloys have the characteristic silvery gray color, light weight, high thermal and electrical conductivity, good corrosion resistance and machinability, tensile strength ranging from 19,000 to 53,000 psi and elongation up to 22 per cent. Mechanical properties can be varied by composition changes and by heat treatment.

Copper-base . . . These alloys have excellent mechanical properties including tensile strengths ranging from 21,000 to 125,000 psi, elongation up to 52 per cent and reduction area up to 40 per cent. Other qualities include corrosion resistance, a range of colors from yellow to red, high thermal and electrical conductivity and good bearing qualities.

Only the aluminum, silicon and beryllium bronzes are hardenable by heat treatment and they give the highest strengths. Other alloys provide variations in mechanical properties through variations in composition. So many combinations have been developed due to the numerous metals which alloy alone and in



BALDWIN-LIMA-HAMILTON CORP. PHOTO

Bronze ship propellers are giant product of nonferrous industry.

combinations with copper, that they are classified broadly according to major variations in composition.

These are: copper, red brass, leaded red brass, semi-red brass, leaded semi-red brass, yellow brass, leaded yellow brass, high strength yellow brass or manganese bronze, leaded manganese bronze, silicon brass or silicon bronze, tin brass (seldom used in foundry work), nickel brass or nickel bronze (German silver or nickel silver), leaded nickel brass or leaded nickel bronze, tin bronze, leaded tin bronze, high leaded tin bronze, lead bronze (used for special bearings), aluminum bronze and beryllium bronze.

Magnesium-base . . . Only two-thirds as heavy as the aluminum alloys and about one-fifth as heavy as the copper alloys, magnesium alloys find their greatest application where high strength in relation to weight is important. Tensile strengths range from 22,000 to 45,000 psi with elongation up to 12 per cent. These alloys are used primarily in aircraft but find other applications where lightness is important. (More details about magnesium castings are covered in the Magnesium Association article appearing in this issue of MODERN CASTINGS.)

Nickel-base . . . alloys in this family provide some of the highest strengths—50,000 to 145,000 psi tensile and elongation up to 45 per cent—as well as extremely high corrosion and heat resistance. Alloys range from those with small percentages of silicon, manganese and carbon, to the monels (contain also important percentages of copper and iron), inconels with chromium and iron, cupro-nickel (45 per cent each), and a variety of others.

Zinc-base . . . These alloys are used almost entirely in die casting or slush casting where they provide tensile strengths of 25,000 to 52,100 psi and elongation up to 10 per cent.

PROCESS POSSIBILITIES

The five families of nonferrous casting alloys can be poured into a variety of types of molds, thus giving the user a number of design possibilities and the flexibility of several methods of production. Not all alloys can be cast economically in all molds, but

COPPER-BASE CASTING ALLOYS[1]

Name of Alloy	Tensile Strength (psi)	Yield Strength (psi)	Elongation % in 2 in.	Brinell Hardness 500-Kg Load	Impact Strength (Izod) ft-lb
Copper – Sand Cast Grade	28,000-30,000	7,000-9,000	45-50	35-40	40-50
Steam or Valve Bronze	36,000-48,000	16,000-21,000	25-40	60-72	11-16
High Leaded Tin Bronze	23,000-38,000	11,000-22,000	7-25	42-70	2-8
Leaded Tin Bronze	36,000-43,000	16,000-24,000	18-30	60-75	12-15
Aluminum Bronze	70,000-110,000	25,000-55,000	12-38	....	7-50
Nickel Aluminum Bronze	90,000 (Min.)	40,000 (Min.)	5 (Min.)	....	....
High Strength Yellow Brass	70,000-120,000	28,000-90,000	12-35	....	7-40
Leaded High Strength Yellow Brass	60,000-78,000	25,000-40,000	15-30	80-95	20-40
Leaded Nickel Bronze	40,000-65,000	17,000-40,000	15-25	76-150	....
Leaded Nickel Brass	30,000-40,000	15,000-20,000	10-25	50-60	....
Silicon Bronze	45,000 (Min.)	18,000 (Min.)	20 (Min.)	80-130	15-60
Silicon Brass	50,000 (Min.)	21,000 (Min.)	16 (Min.)	80-130	15-60
Leaded Yellow Brass	30,000-40,000	11,000-15,000	20-40	40-60	....
Leaded Semi-Red Brass	29,000-40,000	12,000-17,000	18-35	50-60	6-10
Leaded Red Brass	30,000-46,000	12,000-24,000	15-35	50-65	6-12

[1]Data abstracted from CAST METALS HANDBOOK, published by American Foundrymen's Society.

MECHANICAL PROPERTIES[a]

Sand Cast Aluminum Alloys (A.S.T.M. Alloy Specification B-26-54T)

Typical Properties

Alloy	Condition or Temper[c]	Yield Strength (Offset = 0.2%), psi	Tensile Strength, psi	Elongation % in 2 in.	Brinell Hardness, 500kg load, 10mm ball	Shearing Strength psi	Endurance Limit psi[d]
C4A	–T4	16,000	32,000	8.5	60	26,000	7,000
	–T6	24,000	36,000	5.0	75	30,000	7,500
	–T62	32,000	41,000	2.0	90	33,000	8,000
	–T7	19,000	33,000	4.0	70	24,000	....
CG100A	–T2	20,000	27,000	1.0	80	21,000	9,500
	–T61	40,000	41,000	0.5	115	32,000	8,500
CN42A	–T21	18,000	27,000	1.0	70	21,000	6,500
	–T61	32,000	37,000	0.2	105	32,000	8,000
CS43A	–F	14,000	21,000	2.5	55	17,000	11,000
CS72A	–F	15,000	24,000	1.5	70	20,000	9,000
G4A	–F	12,000	25,000	9.0	50	20,000	7,000
G10A	–T4	26,000	48,000	16.0	75	34,000	8,000
GS42A	–F	13,000	20,000	2.0	50	17,000	....
S5A	–F	8,000	19,000	8.0	40	14,000	8,000
S5B	–F	8,000	19,000	8.0	40	14,000	8,000
SC51A	–T6	23,000	35,000	3.0	80	28,000	9,000
	–T51	23,000	28,000	1.5	65	22,000	7,000
	–T71	29,000	35,000	1.5	75	26,000	10,000
SC64B	–F	16,000	27,000	2.5	65	22,000	10,000
	–T6	24,000	35,000	3.5	85	28,000	11,000
SC64C	–F	18,000	27,000	2.0	70	22,000	10,000
	–T6	24,000	36,000	2.0	80	29,000	10,000
SC82A	–F	16,000	27,000	2.5	60	23,000	10,000
	–T6	25,000	37,000	2.5	85	28,000	11,000
SG70A	–T6	24,000	33,000	3.5	70	26,000	8,500
	–T51	20,000	25,000	2.0	60	20,000	7,500
ZC81A	–T5[e]	25,000	35,000	4.5	74	.....	10,000
ZG32A	–T5[e]	20,000	35,000	8.5	65	.....	8,000
G42A	–T5[e]	27,000	38,000	3.0	85	.....	9,000
ZG61A	–T5[e]	25,000	35,000	5.0	70	26,000	9,000
ZG61B	–F	25,000	35,000	5.0	75	.....	8,000

Permanent Mold Cast Aluminum Alloys (A.S.T.M. Alloy Specification B108-54T)[b]

CG100A	–T551	35,000	37,000	0.5	115	30,000	8,500
	–T65	36,000	48,000	0.5	140	36,000	9,000
CN42A	–T571	34,000	40,000	1.0	105	30,000	10,500
	–T61	42,000	47,000	0.5	110	35,000	9,500
CS42A	–T4	19,000	37,000	9.0	75	30,000	9,500
	–T6	26,000	40,000	5.0	90	32,000	10,000
	–T7	20,000	39,000	4.5	80	30,000	9,000
CS66A	–T5	35,000	40,000	0.0	110	.....	....
CS72A	–F	19,000	28,000	2.0	70	22,000	9,500
CS104A	–F	24,000	30,000	1.5	100	24,000	....
GS42A	–F	13,000	22,000	2.0	55	.....	....
GZ42A	–F	16,000	27,000	7.0	60	22,000	....
S5A	–F	9,000	23,000	10.0	45	16,000	....
S5B	–F	9,000	24,000	9.0	45	18,000	....
SC51A	–T6	27,000	42,000	4.0	90	34,000	10,000
SC64A	–F	16,000	28,000	2.0	70	22,000	....
SC64B	–F	19,000	33,000	3.0	70	26,000	12,000
	–T61	30,000	42,000	5.0	85	32,000	14,000
SC64C	–F	19,000	27,000	2.0	70	22,000	10,000
SC122A	–T5	31,000	40,000	0.5	100	.....	13,500
	–T65	35,000	50,000	1.0	120	.....	15,000
SG70A	–T6	27,000	38,000	5.0	85	30,000	13,000
SN122A	–T551	28,000	36,000	0.5	105	28,000	13,500
	–T65	43,000	47,000	0.5	125	36,000	.....
ZC60A	–F	18,000	35,000	8.0	70	.....	11,000
ZC81B	–T5[e]	27,000	40,000	6.0	74	.....	.....
ZG32A	–T5[e]	20,000	40,000	16.0	70	22,000	9,000
ZG42A	–T5[e]	26,000	50,000	8.0	85	38,000	10,000

[a]Tension and hardness values obtained from standard 1/2-in. diameter tensile test specimens, individually cast in green sand molds, and tested without machining off the surface. The modulus of elasticity varies somewhat with the alloy, but an average value of 10,300,000 psi can be used for most calculations.

[b]Same as "a" except specimens are individually cast in a permanent mold.

[d]Based on 500,000,000 cycles of completely reversed stress using the R. R. Moore type machine and specimen.

[c]The temper designation symbols have the following meanings: –F as fabricated; –T2, annealed; –T4, solution heat treated; –T5, artificially aged only; –T6, solution heat treated and then artificially aged; –T7, solution heat treated and then stabilized.

[e]May be aged 21 days at room temperature in lieu of artificial aging.

most nonferrous alloys can be cast into one or more of the following types of molds: 1) green sand, 2) dry sand, 3) shell, 4) CO_2–sodium silicate, 5) plaster, 6) investment, 7) centrifugal, 8) permanent, 9) die.

Choice of process is governed to an extent by the alloy, partly by dimensional tolerances and surface finish required, and partly by the number of castings required. Although virtually all zinc castings and an increasing proportion of aluminum castings are produced in metal molds, most nonferrous castings are produced in sand molds. Maximum dimensional accuracy and smoothest surface possible with sand have not been fully explointed.

HOW YOUR NONFERROUS FOUNDER CAN HELP YOU

Most nonferrous foundrymen are thoroughly familiar with customer problems and desires, and stand ready to help. The customer can serve himself best by conferring with the foundrymen at the design stage. At this point, before final design has been set, the foundryman can advise on the feasibility of casting certain components, recommend proper casting design and pattern equipment and provide quality control and cost information.

In most instances, parts not originally visualized as castings can be changed so that better or more economical castings can be produced without interfering with the function of the parts. Good foundry practice–gating, risering, chilling, padding, use of mold materials of varying thermal conductivity–often makes good castings from bad designs; but is is better for the customer, primarily because it is more economical and because casting quality can be assured, if sensible casting design principles are followed.

Readers of the *NFFS Consumer Survey* know the customer means it when he rates quality first, service second and price third in importance. Foundrymen are ready to lend customers all their knowledge of the mechanical and metallurgical factors of casting design to guarantee that consumers will receive high quality castings, as required, at a fair price.

The MAGNESIUM ASSOCIATION

tells DESIGNERS AND BUYERS why and how to use

JERRY SINGLETON /
Executive Secretary
Magnesium Association
New York

Magnesium castings are characterized by soundness, good surface appearance and high strength-to-weight ratio. They can be obtained in a wide variety of intricate shapes—shapes so complex that they cannot be produced economically by any other metalworking method. Sand, permanent mold, and die casting are the methods most commonly used to produce such cast structures. However, magnesium castings also are made by the plaster mold, centrifugal, shell molding and the precision investment (lost wax) process.

Techniques recently have been developed for producing thin-walled castings as replacements for complicated and expensive fabrications. Such castings are usually made in sand molds, sometimes with special facing sands to obtain better than average surfaces, and also may require the use of plaster or other special cores. Magnesium alloy sand castings can be secured in a large variety of sizes and shapes. Sizes in current production range from castings weighing only a few ounces to those weighing over 1500 pounds.

ALLOY SELECTION

Mg-Al-Zn alloys for sand castings combine high strength and good casting characteristics. Alloys in this system provide stable properties up to around 200F and often give satisfactory service up to as high as 350F, if operating stresses are not too high. The mechanical properties required will usually influence the choice of alloy, all of which are heat treatable to obtain a range of desirable properties. Designation for alloys in this family are AZ63A, AZ81A, AZ91C, and AZ92A. See Table 1 for alloy properties.

For applications requiring excellent strength at temperatures roughly between 350F and 500F, casting alloys containing rare earths are employed. Use of these alloys usually provides a more satisfactory design than is possible with the Mg-Al-Zn alloys. Relatively small differences in properties exist between the Mg-rare earth-Zr alloys EK30A, EK41A and EZ-33A. These three alloys have excellent pressure tightness and good creep strength in the elevated temperature range previously indicated and are heat treatable. The choice between the three alloys is made by the user on the basis of his particular application.

Two thorium containing compositions are being cast as standard alloys—HK31A and HZ32A. Both are utilized for applications in the temperature range of 350F to 650-700F where properties better than those of the rare earth containing alloys are needed. HK31A is particularly good for short time elevated temperature uses where high stresses are encountered, while HZ32A is preferred where long time lower stress properties are important. The creep characteristics of the thorium compositions are much superior to those of the Mg-Al-Zn and the Mg-rare earth alloys.

SAND CASTINGS

A nominal tolerance of plus or minus 1/32-in. is maintained on sand casting dimensions. Dimensional tolerances will vary somewhat, depending upon the individual casting. In some cases it is possible to

Aircraft wheels benefit from low weight of cast magnesium. Largest weighs 170 lb.

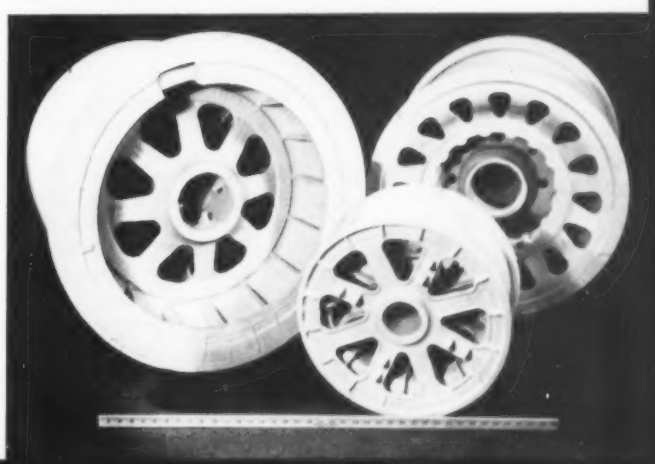


TABLE I – PROPERTIES OF CAST MAGNESIUM ALLOYS

form	alloy	temper[1]	Room temperature mechanical properties[2] tensile strength 1000 psi typ.	tensile strength 1000 psi min.	tensile yield strength[3] 1000 psi typ.	tensile yield strength[3] 1000 psi min.	elongation in 2"–% typ.	elongation in 2"–% min.	compressive yield strength 1000 psi typ.	compressive yield strength 1000 psi min.	shear 1000 psi	bearing strength 1000 psi ult.	bearing strength 1000 psi yield	hardness Brinell	hardness Rockwell E	temper[1]	alloy
sand and permanent mold casting alloys	AZ63A	–F	29	24	14	10	6	4	14	–	18	60	40	50	59	–F	AZ63A
		–T4	40	34	14	10	12	7	14	–	18	60	44	55	66	–T4	
		–T5	29	24	14	11	5	2	–	–	19	60	40	–	–	–T5	
		–T6	40	34	19	16	5	3	19	–	21	75	52	73	83	–T6	
	AZ81A	–T4	40	34	14	10	12	7	14	–	18	60	44	55	66	–T4	AZ81A
	AZ91C	–F	24	18	14	10	2	–	14	–	18	50	30	52	62	–F	AZ91C
		–T4	40	34	14	10	11	7	14	–	18	50	36	55	66	–T4	
		–T6	40	34	19	16	4	3	19	–	21	65	45	73	83	–T6	
	AZ92A	–F	24	20	14	10	2	1	14	–	19	50	46	65	77	–F	AZ92A
		–T4	40	34	14	10	10	6	14	–	19	68	46	63	75	–T4	
		–T5	24	20	14	11	2	–	–	–	20	50	46	–	–	–T5	
		–T6	40	34	21	18	2	1	21	–	22	80	65	84	90	–T6	
	EK30A	–T6	23	20	16	14	3	2	16	–	–	–	–	45	49	–T6	EK30A
	EK41A	–T5	23	20	16	14	1	–	16	–	–	–	–	45	49	–T5	EK41A
		–T6	25	22	18	16	3	1	18	–	–	–	–	50	59	–T6	
	EZ33A	–T5	23	20	15	14	3	2	15	–	–	–	–	50	59	–T5	EZ33A
	HK31A	–T6	30	27	15	13	8	4	15	–	–	61	40	55	66	–T6	HK31A
	HZ32A	–T5	29	27	14	13	7	4	14	–	–	–	–	57	68	–T5	HZ32A
	ZH62A	–T5	40	35	26	22	8	4	26	–	–	–	–	–	–	–T5	ZH62A
	ZK51A	–T5	40	34	26	20	8	5	26	–	22	72	47	65	77	–T5	ZK51A
permanent mold casting alloy	AM100A	–F	22	20	12	10	2	–	12	–	17	–	–	54	65	–F	AM100A
		–T4	40	34	13	10	10	6	13	–	19	–	–	52	62	–T4	
		–T6	40	34	16	15	4	2	16	–	21	–	–	69	80	–T5	
		–T61	40	34	22	17	1	–	22	–	–	–	–	–	–	–T6	
die casting alloy	AZ91A & AZ91B	–F	33	–	22	–	3	–	22	–	20	–	–	60	72	–F	AZ91A & AZ91B

Yield strength is defined as the stress at which the stress-strain curve deviates 0.2% from the modulus line.

[1] Temper: –T4 = solution heat treated. –T6, –T61 = solution heat treated and artificially aged. –F = as fabricated. –T5 = artificially aged.

[2] Unless otherwise indicated, values are typical.

hold tolerance on casting dimensions closer than 1/32-in.; in other cases 1/32-in. cannot be met. Thickness limitations are approximately the same as for other non-ferrous metals.

Wood patterns are often used, especially when runs are small. The use of wood permits changes in the casting design without great increase in cost. For short runs, loose or matchplate patterns can be used, but full cope and drag equipment is recommended for production runs.

Pattern equipment designed for magnesium should have generous fillets and radii. Section changes should be gradual to reduce chances for stress concentration. Shrinkage allowance for pattern design depends on the mold material, the alloy to be poured and the geometry of the part. This allowance may vary from 0.1 in. to 3/16-in. per foot, depending on the above mentioned factors.

When the number of parts is sufficient to justify the added cost, metal patterns are desirable since they allow closer dimensional control and better surface finish. It should be emphasized that in order to obtain the best castings possible, close cooperation between customer and foundry should begin before patterns are made, and pattern equipment designed for the casting of magnesium should be used.

Precautions should always be taken to avoid conditions leading to local stress concentrations in magnesium alloy castings. Tool marks, notches and sharp corners provide such stress concentrations and should be eliminated, particularly if the castings are subject to vibration or frequent reversals of stress. Generous fillets and radii, beaded holes and gradual section changes will insure against such concentrations of stress. Particular attention should be paid to section changes. Where a relatively thin wall joins a thicker wall or a large boss, the thin wall should be gradually tapered or blended into the heavier section.

Bushings, bearings and threaded inserts can be cast into place in magnesium alloy sand castings. It is important to provide ample metal thickness around the cast-in insert. Steel inserts are used in preference to brass bronze or other nonferrous metals. Another recent tend has been toward cast-in passageways instead of casting-in tubes or drilling passages.

Magnesium sand castings can be heat treated to improve their properties. Several types of heat treatment have been developed and selection of the proper schedule for use depends upon the service requirements of the casting.

Solution heat treatment is given to improve tensile strength, ductility and shock resistance. This heat-treated condition is indicated by using the symbol "-T4" following the alloy letters. Solution heat treatment plus artificial aging, designated as "-T6", results in improved tensile yield strength and hardness. The artificial aging heat treatment of "as cast" parts is designated as "-T5" and improves the mechanical properties somewhat and results in increased growth stability at elevated temperatures.

PERMANENT MOLD CASTINGS

Magnesium alloys are cast by the permanent mold process when the quantity of parts required justifies the cost of the equipment—at times as few as 1000 pieces. Factors such as the amount of production and the relative cost of parts will determine whether permanent molds or sand molds should be used. Permold castings will have mechanical properties very similar to those of sand castings. The permanent mold casting process enables closer control on dimensions to be maintained which means savings in weight and in the amount of necessary machine work. In addition to these advantages, better cast surfaces are obtained.

In general, castings to be produced by permanent mold methods should be relatively simple in design with fairly uniform wall sections and without undercuts or complicated internal coring. The presence of undercuts on the outside of the casting complicates construction of the mold, and a consequent increase in operating costs is caused by additional mold parts. Where undercuts or relatively complicated coring are necessary, or where economy does not permit the use of full permanent mold equipment, semi-permanent molds can be used.

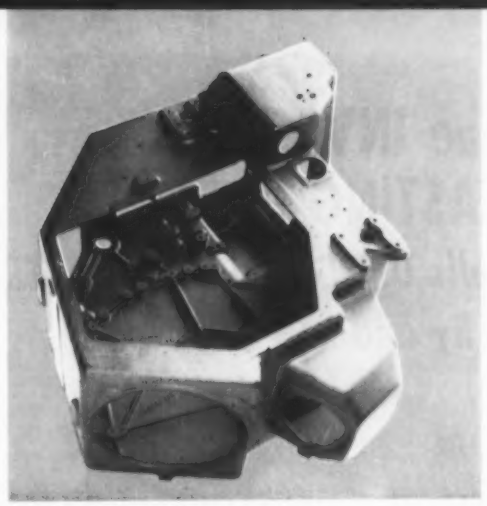
DIE CASTING

Magnesium alloys are well adapted to the die casting process. Magnesium die castings possess many of the advantages of sand and permanent mold castings plus such additional advantages as extremely accurate dimensions, excellent surface finish, lower cost in quantity production, minimum amount of machining required and additional weight saving by virtue of the thin sections possible.

The fact that molten magnesium does not react with iron is an important consideration in its use as a die casting metal. A minimum of die surface treatment is required which permits rapid production from the machine.

Because magnesium does not solder to the die, it is possible to cast small diameter cored holes with ittle or no taper and to employ complicated coring. Magnesium's fast rate of cooling is also important in keeping production rates high. Good dimensional accuracy can be maintained because magnesium die castings possess freedom from growth.

Casting design should be as simple as possible, since the simpler the part, the lower the tooling cost and the cheaper the price per piece. General design considerations will include the use of generous fillets and radii, uniformity of wall or section thickness, the avoidance of abrupt section changes and other features which would tend to cause concentration of stress. Good magnesium die casting design follows the same principles established for other metals.



Airborne camera body casting has 1/8-in. wall.

One important factor in connection with design of die castings is often overlooked, i.e., close cooperation between designer and die caster before the final drawings of a given part are made. At this point, modifications needed because of certain characteristics and limitations of both process and material can be made with a minimum of time, effort and expense.

Section sizes are somewhat limited, but enough latitude can be secured to produce a wide variety of parts. The preferred section thicknesses for magnesium die castings range from 1/16-in. to 3/16-in., with a minimum thickness of 0.050 in. being recommended. The maximum mechanical properties of magnesium die castings are achieved in this thickness range. Sections should rarely exceed 1/4-in. in thickness.

Magnesium die castings do not require heat treating and are usually furnished with an untreated surface. Decorative paint finishes or electroplating may be applied to magnesium die castings.

In general, the versatility of magnesium makes it applicable in any casting situation. Where light weight high damping capacity, high strength-to-weight ratio or minimized machining time are either essential or desirable, magnesium has attributes which dictate its serious consideration and careful evaluation.

Thin-wall casting is air scoop for missile.

The INVESTMENT CASTING INSTITUTE

tells DESIGNERS AND BUYERS why and how to use

R. R. MILLER /
President
Investment Casting Institute
Chicago

INVESTMENT Castings

Current events and market trends are demanding that design engineers seek new materials and more modern methods of fabrication to produce better parts at a higher rate with lower costs. This tremendous task is covered by the simple phrase "value analysis." The investment casting industry has been able to contribute greatly to the fulfillment of this need.

Investment castings are solving difficult fabricating problems, accomplishing breakthroughs in many projects and considerably shortening manufacturing lead time.

It has been taught that "Casting is the shortest distance between material and finished product." This distance is shortened even more by investment castings which offer closer tolerances, better surface finish and parts cast in almost any alloy to the optimum of desired shape.

DESIGN FOR INVESTMENT CASTING

Investment casting offers greater freedom of design than any other metal forming operation. Design engineers can have the simplest to the most complex designs cast as a single unit from any castable alloy. In fact, almost any shape which can be drawn can be investment cast when sound casting procedures are followed and proper gating is permitted.

Basic laws of metal flow, solidification and behavior have been established and hold true in *all* casting methods. Designers of investment castings follow these same principles but more closely due to the very complex shapes poured from higher temperature alloys.

Three of the most important elements of good casting design would include:

1. Proper gating of the part.
2. Uniform wall sections.
3. Minimizing non-functional mass.

PROPER GATING

Molten metal shrinks as it solidifies. For this reason a casting is gated into the heaviest areas which permits the metal to flow into the thinner sections. The thin sections solidify first. Shrinkage here is "fed" or filled from the still molten metal of the adjacent heavier areas. These in turn solidify and as they shrink are filled from the gates and sprues. This "directional solidification" is required to produce a sound casting.

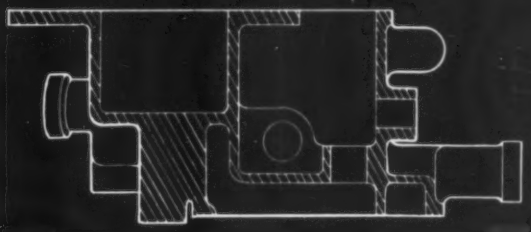
When heavy areas are joined by thin sections each of the heavy areas must be properly gated. If only one heavy area is gated the molten metal will solidify in the connecting thin section. Then the flow of molten metal to the adjoining heavy area is "frozen-off" before it is completely filled. Shrinkage porosity results. This can only be eliminated by gating all heavy areas joined by thin sections. The design engineer must remember this simple rule and permit proper gating by the foundry. The casting in Fig. 1 illustrates this design element.

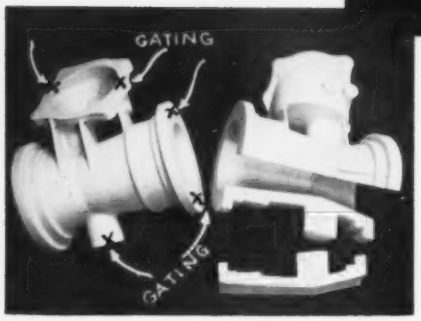
UNIFORM WALL SECTION

Wall thickness of a casting should be as uniform as possible and without sharp, abrupt changes in sections. If abrupt section changes are necessary, use radii and fillets to reduce the turbulence of metal flow. This in turn relieves stress concentrations and porosity in these areas after metal solidification. The casting in Fig. 2 and its cross-section in Fig. 3 illustrate this point. Note gating into the heavy areas to

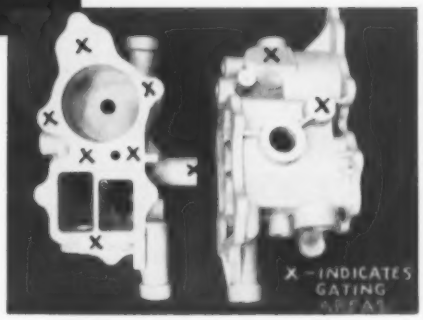
General Characteristics of Investment Castings

Alloy Groups	Average Tensile Strength (psi) As-Cast	Heat Treated
Aluminum	30,000	45,000
Beryllium Copper	75,000	175,000
Nickel-base alloys	65,000	200,000
Carbon & Low Alloy Steel	70,000	170,000
Stainless Steel	60,000	227,000
High Temperature Steel	80,000	125,000
Tool Steel	100,000	150,000
As-Cast dimensional tolerance	± 0.005 in./in.	
As-Cast surface finish	40–125 rms	
Range of casting weights	1/20 gram–200 lb.	
Range of casting size	1/8 in.–42 in. in any direction	





Gating principles. Fig. 1 (left) shows gating where heavy areas are joined to thin. **Fig. 2** (above) and **Fig. 3** (right) illustrate gating into the heavy areas of the part.



minimize non-functional mass and the ribbing which serves to control warpage.

NON-FUNCTIONAL MASS

Metal solidifying in a heavy mass tends to develop shrinkage porosity because it is difficult to provide sufficient gating to "feed" the part.

An important advantage to casting is the ability to place metal where needed. In Fig. 4, the masive, non-functional areas were lightened, structural strength was supplied by ribs and a sound part was obtained at a lower cost.

CAST PROTOTYPES DESIGN AID

Engineers often wish, when designing new parts or re-designing old parts, that several unknown factors could be determined before the parts are released to production:

1. Will the alloy chosen perform properly?
2. Is the design most economical and will it fully serve the intended purpose?
3. Will the part function as required?
4. Could only a few parts be obtained for testing before tooling is ordered?
5. How can development costs be reduced?
6. How can development time be speeded?

The investment casting industry makes available a prototype technique which can be used as a simple, inexpensive method of evaluating designs. By using polystyrene or wax patterns for cast prototypes, it is possible to prove a design or alloy before buying expensive tooling.

This prototype technique eliminates guesswork and encourages healthy experimentation with considerable savings in time and money in the research and development of a new design or product.

Often several designs of a given part are required to determine the most functional casting. Radical design changes are not easily effected nor feasible in a machined steel die.

Fig. 4 . . ribs are used both to lighten and strengthen the part.

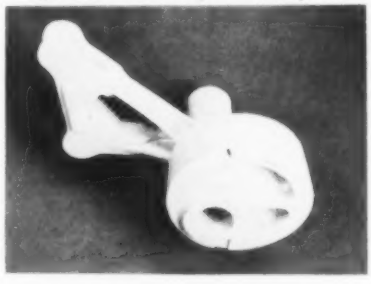


Figure 6 shows an example of how to produce an investment casting for prototype testing of a new part without tooling.

These components could be rearranged into as many different designs as required for test purposes of the cast parts. For instance: the four appendages could be placed on the O.D. of the castings in unlimited positions simply by fastening them on with plastic adhesive.

PROPERTIES OF INVESTMENT CASTINGS

Comprehensive and authoritative re-evaluation of castings versus other types of formed parts has proved that the properties of castings compare equally or better in several respects.

Until recently it has been an almost overlooked fact that an important physical property of a metal is its "modulus of elasticity"—its rigidity in the elastic stage before the yield strength is reached. This property, the same for any type of metal, is dependent only on cross-sectional area, regardless of cast or other origin, and cannot be changed. On the basis of this property, investment castings compete equally with other formed parts.

An investment casting has random grain orientation and the properties are the same in every direction. This property is called "isotropic" or "omni-directional." The casting is equally strong in every direction while in some mechanically-formed parts the transverse properties are greatly lower than the longitudinal.

The omni-directional grain structure of an investment casting absorbs vibration without transmitting it. This characteristic eliminates the "flutter" that is often detected in metals of fibrous structure which sustain and conduct vibration.

Investment castings have superior ability to resist sudden brittle and fatigue fracture. They are particularly amenable to streamlining with correct radii so necessary to

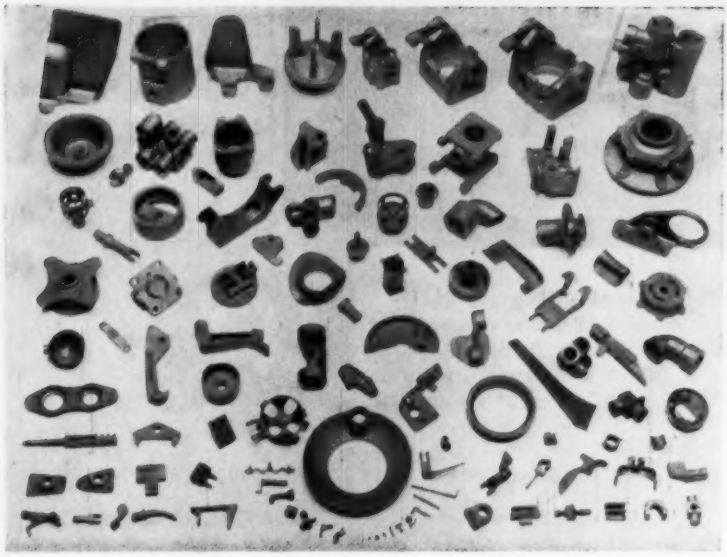


Fig. 5 . . well designed ferrous investment castings made in stainless steels, carbon steels and high temperature steels for aircraft, missiles, textile and food machinery, machine tools and business machines.

reduce stress concentration to a minimum. Often stress concentration can be reduced by half with proper radii in fillets and changes in section, doubling the actual load carrying ability of the part.

Extremely thin sections, knife edges and sharp detail can only be obtained in castings by the use of hot molds as utilized in investment casting. Hot molds have a second equally important function. They improve metal flow so it can be poured colder. The less metal is heated above its melting point, the less chance of burning off any of the alloying elements. Investment castings maintain close control of chemical analysis as the hot mold permits casting without overheating the metal.

Thin sections are more pressure tight through the elimination or reduction of internal porosity and are held to closer tolerances because there is less metal to shrink in solidifying.

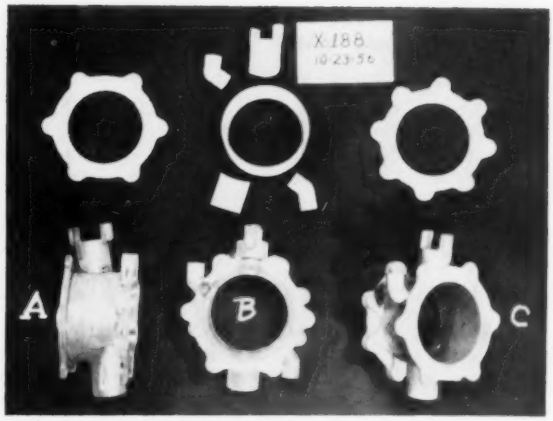


Fig. 6 . . Machined polystyrene components of a prototype pattern. A and B are assembled patterns. C is a casting made from the pattern.

Fig. 7 . . Well designed nonferrous investment castings made in beryllium copper, aluminum, silicon brass and silicon bronze for aircraft, missiles, pneumatic tools, electronic equipment and textile machinery.

The AMERICAN DIE CASTING INSTITUTE

tells DESIGNERS AND BUYERS why and how to use

DAVID LAINE /
Secretary
American Die Casting Institute
New York

During the last decade when the custom (job-shop) producers of die castings in this country have almost trebled their annual rate of production of die castings for incorporation as parts, sub-assemblies and assemblies for practically all segments of industry, product engineers have been assisted immeasurably by programs sponsored by the 124 custom die casting companies comprising the American Die Casting Institute. Their approach to selling has brought about a situation whereby it is becoming the rule, rather than the exception, for customers to call in the die casting engineer during the very early stages of product design.

When and Where Die Castings Are Used

While the die casting process is, by no means, a cure-all for all the problems of metal parts fabrication, the remarkable growth of die casting usage in the past ten years testifies to the ability of the custom die casters to offer both economies and properties which excell those offered by other production methods. The following table, for example, indicates the recent widening field of application and acceptance for aluminum and zinc die castings where non-ferrous castings are involved:

Die Castings—Per Cent of Total Non-Ferrous Castings Metal	1955	1956	1957
Aluminum	43.0	47.3	49.0
Zinc	91.0	98.9	99.0

Die castings have made similar gains in relation to other forms of fabrication for non-ferrous parts such as stampings, screw machine products and forgings.

Problems Of Over-Specification

It is axiomatic that the lowest possible piece cost and the most efficient performance of any die casting will result when full advantage is taken of the inherent advantages of the process. As with other forms of metal parts production, however, the costly problem of over-specification still prevails in many quarters. The design engineer can avoid the over-specification pitfall by using the A.D.C.I. product standards for die castings.

Guides for Design Engineers and Buyers

In publishing product standards, the A.D.C.I. has established values which represent normal die casting production practice at the most economic level. The standards are not intended as maximal specifications. They emphasize the fact that greater accuracy involving extra close work or care in production should only be specified where actually needed, since additional cost will inevitably be involved.

The A.D.C.I. product standards are composed of an (E) engineering, (M) metallurgical and a (C) commercial series. The E series covers all types of tolerances (linear, parting line, moving die part, flatness, angularity and concentricity) as well as specific data on draft requirements, cored holes, ejector pin marks, flash removal and other details of design requirements. The M series covers information on the mechanical properties and physical constants of die castings. Included are alloy compositions, properties and characteristics of zinc, aluminum, magnesium and brass die castings, together with cross reference charts. The C series covers the principal provisions specific to die casting purchasing contracts. This series informs the die casting buyer as to the prevailing and customary arrangements normally found in the proposal and acknowledgment forms used by the die casting industry.

Because of space limitations in this article it is only possible to reproduce a few of the representative A.D.C.I. product standards that are of paramount interest to casting designers and buyers. **See page 46.**

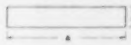
Casting designers and buyers can obtain a complete set of these die casting standards from A.D.C.I. and will find them a very helpful guide in making decisions involving their future products.

PRODUCT STANDARDS FOR DIE CASTINGS

ADCI-E1-53T
LINEAR DIMENSION TOLERANCES

NOTE — The values shown herein represent normal production practice at the most economic level. Greater accuracy involving extra close work or cores in production should be specified only when and where necessary since additional cost may be involved.

LINEAR DIMENSION TOLERANCES, AS CAST.



The tolerance on a dimension "A" will be the value shown in the table. This tolerance must be increased where the parting line of the die, or moving die parts, affect dimension "A". (See Standard E2 and E3)

TOLERANCES FOR CRITICAL DIMENSIONS (THREE PLACE DECIMALS) IN INCHES

Length of Dimension "A"		DIE CASTING ALLOY			
		ZINC	ALUMINUM	MAGNESIUM	COPPER
Basic Tolerance up to 1"		± .002	± .004	± .004	± .007
Additional Tolerance for each additional inch of Dim. "A"	Over 1" to 12"	± .001	± .0015	± .0015	± .002
	Over 12"	± .001	± .004	± .001	XX

EXAMPLE: An aluminum die casting would have on a 4.000" Dimension "A" a tolerance of ± .0035" if that dimension is not affected by a parting line or moving die part.

TOLERANCES FOR NON CRITICAL DIMENSIONS (FRACTIONAL OR TWO PLACE DECIMALS) IN INCHES

Length of Dimension "A"		DIE CASTING ALLOY			
		ZINC	ALUMINUM	MAGNESIUM	COPPER
Basic Tolerance up to 1"		± .010	± .010	± .010	± .014
Additional Tolerance for each additional inch of Dim. "A"	Over 1" to 12"	± .0015	± .002	± .002	± .003
	Over 12"	± .001	± .001	± .001	XX

NOTE: The tolerances shown above must be modified if a parting line or moving die part affects Dimension "A".

PRODUCT STANDARDS FOR DIE CASTINGS

ADCI-D6-53T
DEPTH OF CORED HOLES

NOTE — The values shown herein represent normal production practice at the most economic level. Greater depth involving extra close work or cores in production should be specified only when and where necessary since additional cost may be involved.

CORED HOLES

Optimum greatest depth of cored holes as related to diameter is shown in the table. The values shown for hole depths are subject to the draft requirements shown in ADCI Product Standard E7.

Requirements for tapped holes are shown in ADCI Product Standard E8.

ALLOY	DIAMETER OF HOLE — INCHES								
	⅛	3/16	1/4	5/16	3/8	½	⅝	¾	1
	MAXIMUM DEPTH — INCHES								
Zinc*	⅜	9/16	¾	1	1½	2	2½	4½	6
Aluminum*	9/16	¾	⅞	1	1½	2	2½	4½	6
Magnesium*	9/16	¾	⅞	1	1½	2	2½	4½	6
Copper				½	1	1½	2	2½	5

* For cores larger than 1" in diameter the diameter-depth shall be 1-1.

NOTE — The depths shown are not applicable under conditions where small diameter cores are widely spaced and, by design, are subject to full shrinkage cross.

PRODUCT STANDARDS FOR DIE CASTINGS

ADCI-E3-53T
PARTING LINE TOLERANCES

NOTE — The values shown herein represent normal production practice at the most economic level. Greater accuracy involving extra close work or cores in production should be specified only when and where necessary since additional cost may be involved.

PARTING LINE TOLERANCES — IN ADDITION TO LINEAR DIMENSION TOLERANCES (BASED ON SINGLE CAVITY DIE)

Parting Line Tolerances, in addition to Linear Dimension Tolerances, must be provided when the parting line affects a linear dimension.

"Projected Area" is the area of the die casting in square inches at the die parting plane.

ADDITIONAL TOLERANCES IN INCHES

Projected Area of Die Casting	DIE CASTING ALLOY			
	ZINC	ALUMINUM	MAGNESIUM	COPPER
Up to 50 sq. inches	± .004	± .005	± .005	± .005
50 to 100 sq. inches	± .006	± .008	± .008	——
100 to 200 sq. inches	± .008	± .012	± .012	——
200 to 300 sq. inches	± .012	± .015	± .015	——

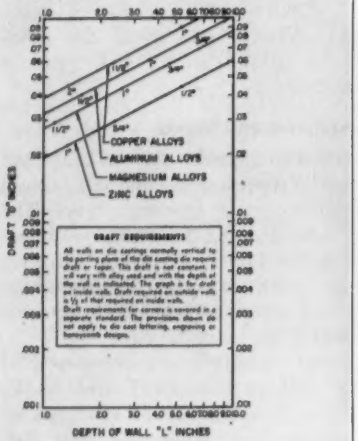
NOTE: The above tolerances are to be added to Linear Tolerances worked out for a dimension as provided in Standard E1.

Additional tolerances in the case of moving die parts are shown in Standard E3.

PRODUCT STANDARDS FOR DIE CASTINGS

ADCI-E4-53T (Page 2)
DRAFT REQUIREMENTS FOR WALLS (OVER ONE INCH IN DEPTH)

NOTE — The values shown herein represent normal production practice at the most economic level. Greater accuracy involving extra close work or cores in production should be specified only when and where necessary since additional cost may be involved.

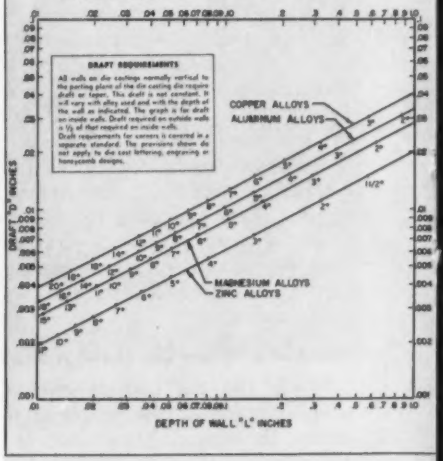

DRAFT "D" INCHES
DEPTH OF WALL "L" INCHES
COPPER ALLOYS
ALUMINUM ALLOYS
MAGNESIUM ALLOYS
ZINC ALLOYS
DRAFT REQUIREMENTS
All walls on die castings normally vertical to the parting plane of the die casting die require draft or taper. This draft is not constant. It will vary with alloy used and with the depth of the wall as indicated. The graph is for draft on inside walls. Draft required on outside walls is ½ of that required on inside walls. Draft requirements for corners is covered in a separate standard. The provisions shown do not apply to die cast lettering, engraving or honeycomb designs.

19 components of lawn mower are zinc and aluminum die castings

PRODUCT STANDARDS FOR DIE CASTINGS

ADCI-E4-53T (Page 1)
DRAFT REQUIREMENTS FOR WALLS (LESS THAN ONE INCH IN DEPTH)

NOTE — The values shown herein represent normal production practice at the most economic level. Greater accuracy involving extra close work or cores in production should be specified only when and where necessary since additional cost may be involved.


DRAFT "D" INCHES
DEPTH OF WALL "L" INCHES
DRAFT REQUIREMENTS
All walls on die castings normally vertical to the parting plane of the die casting die require draft or taper. This draft is not constant. It will vary with alloy used and with the depth of the wall as indicated. The graph is for draft on inside walls. Draft required on outside walls is ½ of that required on inside walls. Draft requirements for corners is covered in a separate standard. The provisions shown do not apply to die cast lettering, engraving or honeycomb designs.
COPPER ALLOYS
ALUMINUM ALLOYS
MAGNESIUM ALLOYS
ZINC ALLOYS

PRODUCT STANDARDS FOR DIE CASTINGS

ADCI-M2-53T
COMPOSITION AND PROPERTIES OF STANDARD ALUMINUM BASE ALLOY DIE CASTINGS

ALUMINUM BASE ALLOY DIE CASTINGS

1. **Alloy Selection — STANDARD ALLOYS**

The aluminum alloys most generally used are shown below. Die casting and other processing characteristics data involved in alloy selection are covered in ADCI M4. Special Aluminum Alloys are shown in ADCI M5. Special alloys should be selected only when the nature of the requirement justifies the higher metal and processing costs involved.

2. **Composition and Properties**

The chemical compositions of STANDARD ALUMINUM BASE ALLOY DIE CASTINGS and related typical values for physical properties and constants are shown in the table. The typical values indicated are for separately die cast test-bars and do not represent values for specimens cut from die castings.

CHEMICAL COMPOSITION AND PROPERTIES: ALUMINUM ALLOY DIE CASTINGS		
Designation	Standard Alloys*	
Commercial ASTM	13 S113B	380 SC84B
Composition-per cent (1)		
Copper	0.6	3.5-4.5
Iron	2.0	2.0
Silicon	11.0-13.0	7.5-9.5
Manganese	0.35	0.50
Magnesium	0.10	0.10
Zinc	0.50	1.0
Nickel	0.50	0.50
Tin	0.15	0.35
Total Others	0.25	0.50
Aluminum	Remainder	Remainder
Properties and Constants (2)		
Tensile Strength psi	35,000	45,000
Yield Strength (0.5% offset) psi	21,000	23,000
Elongation, % in 2 in.	2.0	2.0
Shear Strength, psi	25,000	28,000
Fatigue Strength, psi (3)	13,000	20,000
Specific Gravity	2.65	2.71
Weight per cu. in., lbs.	0.096	0.098
Melting Point (Liquid), °F	1080	1100
Thermal Conductivity, CGS	0.23	0.33
Thermal Expansion, in/in/°F (4)	11.9	12.1
Electrical Conductivity, % of Copper Standard	31	33

(1) Composition in per cent, maximum values shown as range, items as ASTM B85.
(2) Data furnished by Aluminum Company of America and ASTM B85. Revisions are in progress and will be made from time to time.
(3) R.R. Moore rotating beam test data at 500,000,000 cycles.
(4) To be multiplied by 10⁻⁶. Temperature range 68° to 302°F.
*These Standard Alloys are also available with 1.3% maximum iron content (designated 13X and A380) having 3% elongation.

PRODUCT STANDARDS FOR DIE CASTINGS

ADCI-M9-57T
COMPOSITION AND PROPERTIES OF ZINC BASE ALLOY DIE CASTINGS

ZINC BASE ALLOY DIE CASTINGS

1. **Alloy Section**

The zinc base alloy shown below is the composition generally used. The alloy is available with more rigid copper limits for special applications where the nature of the requirement justifies the higher metal and processing costs involved.

2. **Chemical Composition**

The chemical composition of zinc base alloy die castings, as shown in the table, is assumed under the conforming analyses provided in the Certified Zinc Alloy Plan for Die Castings, see ADCI-M11.

CHEMICAL COMPOSITION: ZINC ALLOY DIE CASTINGS	
Designation	Standard Alloy
Composition — per cent (1)	
Copper — (Special Note A)	0.0 — 1.25
Aluminum	3.5 — 4.3
Magnesium	0.03 — 0.08
Iron	0.10
Lead	0.007
Cadmium	0.005
Tin	0.005
Zinc	Remainder (2)

(1) Composition in per cent, maximum values shown as a range.
(2) Zinc alloy die castings 3A, 5A, 7A, 26A, and 3 respectively. No harmful effects have ever been noted due to the presence of these elements in these concentrations and therefore analyses are not required for these elements.
SPECIAL NOTE A: For special applications the alloy may be obtained with less than 0.25% copper (ASTM designation, AG40A) or with copper content of 0.75% - 1.25% (ASTM designation, AG41A). For the majority of zinc castings requirements, a copper content in the range of 25-.75% will not adversely affect the serviceability of die castings and should not serve as a basis for rejection.

3. **Properties and Constants**

Typical properties and constants are shown in the table below. The values indicated are for separately die cast test bars and do not represent values for specimens cut from die castings.

TYPICAL PROPERTIES: ZINC ALLOY DIE CASTINGS	
Properties and Constants — (3)	(Special Note B)
Tensile Strength, psi	41,000 — 47,000
Elongation, % in 2 in.	10 — 7
Impact Strength, Charpy, ft. lbs.	45 — 40
Shear Strength, psi	31,000 — 33,000
Specific Gravity	6.6
Weight per cu. in., lbs.	.24
Melting Point (Liquids) °F	727.0
Thermal Expansion, in/in/°F (4)	15.2
Electrical Conductivity, % of Copper Standard	25

(3) Data furnished by New Jersey Zinc Co., ASTM B86, and ASDC.
(4) To be multiplied by 10-6.
SPECIAL NOTE B: Values are typical and where double figures are shown they represent the properties for copper content at minimum and maximum of composition.
SEE ADCI M10 for Characteristics of Zinc Base Die Castings and M11 for Certified Zinc Die Castings.

PRODUCT STANDARDS FOR DIE CASTINGS

ADCI-M7-56T
COMPOSITION AND PROPERTIES OF MAGNESIUM BASE ALLOY DIE CASTINGS

MAGNESIUM BASE ALLOY DIE CASTINGS

1. **Alloy Selection**

The magnesium alloy shown below is the standard composition generally used. This standard alloy is available in a high purity composition with 0.10 maximum copper content, (designated AZ 91A) having improved corrosion resistance.

2. **Composition and Properties**

The chemical compositions of MAGNESIUM BASE ALLOY DIE CASTINGS and related typical values for physical properties and constants are shown in the table. The typical values indicated are for separately die cast test-bars and do not represent values for specimens cut from die castings.

CHEMICAL COMPOSITION AND PROPERTIES: MAGNESIUM ALLOY DIE CASTINGS	
Designation	Standard Alloy
Commercial and ASTM	AZ91D
Composition-per cent (1)	
Aluminum	8.3 to 9.7
Zinc	0.4 to 1.0
Manganese, min.	0.13
Silicon, max.	0.5
Copper, max.	0.30
Nickel, max.	0.05
Others, total, max.	0.2
Magnesium	Remainder
Properties and Constants (2)	
Tensile Strength, psi	34,000
Tensile Yield Strength (0.2% offset) psi	23,000
Elongation, % in 2 in.	3
Shear Strength, psi	20,000
Compressive Yield Strength, psi	22,000
Ultimate Compressive Strength, psi	58,000
Fatigue Strength, psi (3)	14,000
Specific Gravity	1.80
Weight per cu. in., lb.	0.066
Thermal Conductivity, CGS	0.17
Thermal Expansion, in./in./°F (4)	15.2
Electrical Conductivity, % of Copper Standard	10

(1) Composition in per cent as shown, Cf. ASTM B94.
(2) Data furnished by Dow Chemical Co., ADCI, ASTM.
(3) R.R. Moore rotating beam test of 500,000,000 cycles.
(4) To be multiplied by 10⁻⁶. Temperature range 68° to 302°F.

See ADCI M8 for characteristics of Magnesium Alloy Die Castings.

GENERAL MOTORS DESCRIBES CENTRASTEEL . .

W. B. LARSON / *Research Engineer, Research Laboratories*

C. F. JOSEPH / *Technical Director, Central Foundry Div.*

F. J. WEBBERE / *Supervisor, Metallurgical Engineering Research Laboratories*

R. F. THOMSON / *Head, Metallurgical Engineering Research Laboratories*
General Motors Corp.

A new steel-like material having a compacted type of graphite in the as-cast condition is described. Although castability is only slightly inferior to pearlitic malleable iron, an elastic modulus of 28 million psi puts CentraSteel into the steel classification. Use in the as-cast condition is possible due to the absence of massive carbide, while a wide range of properties is obtainable with a series of rather simple heat treatments. This unique material is produced by inoculation with boron and tellurium of a low carbon, high silicon base composition.

CentraSteel was the result of a research program which was intended to determine a means of producing an as-cast malleable iron. The outstanding characteristic of CentraSteel, therefore, is the presence in the as-cast condition of a compacted type of graphite similar to the temper carbon of malleable iron. Mechanical properties obtainable are superior to pearlitic malleable iron, the most important property being a high elastic modulus approaching that of steel. This new material, therefore, should be particularly applicable to highly stressed parts.

Although new concepts of foundry technology are introduced, CentraSteel does not require extensive heat treatment, explosive or costly addition agents, injection apparatus or low maximum sulfur content.

CentraSteel was a cooperative development between the Central Foundry Div. and the Research Laboratories of General Motors Corp.

This paper is intended to describe the salient features of CentraSteel with respect to its chemical composition, mechanical properties, heat treatment and important aspects of its production.

COMPOSITION AND INOCULANTS

Acceptable composition limits, necessary to achieve optimum properties, are given in Table I. A comparison of the preferred carbon and silicon content with commercial gray iron, malleable iron, nodular iron and cast graphitic steel is illustrated in Fig. 1. It is

TABLE I—Preferred Composition Range of CentraSteel

	Min.	Max.	Preferred
Carbon	1.55	1.85	1.70
Silicon	2.20	2.60	2.25
Manganese	0.30	0.80	0.40
Sulfur	0.05	0.20	0.10
Phosphorus			0.05
Boron			0.01

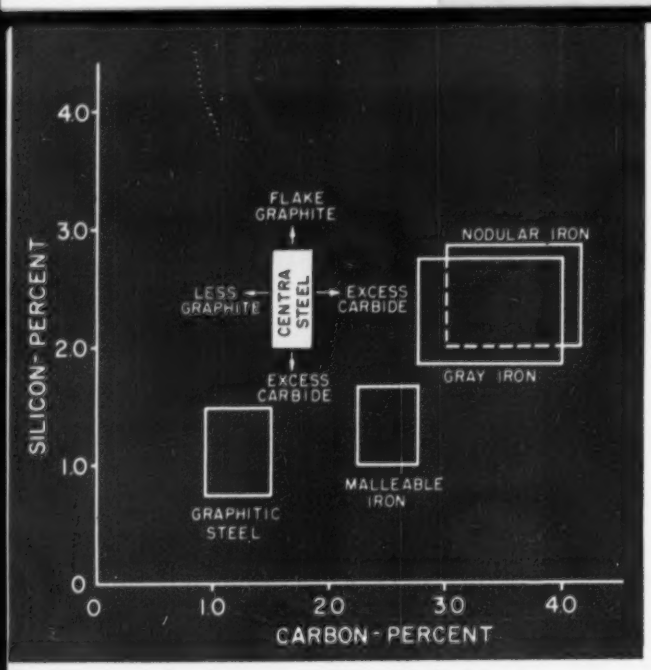


Fig. 1 . . Carbon and silicon range for CentraSteel in comparison with other ferrous materials.

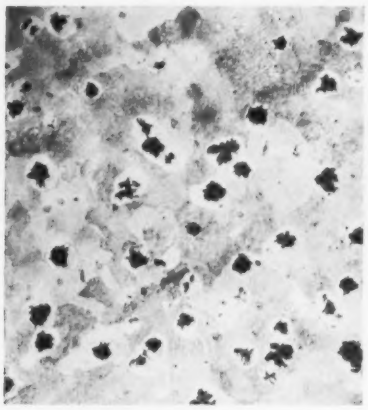


Fig. 2 . . As-cast microstructure of CentraSteel.

immediately seen that the high silicon and low carbon content is the reverse of normal iron founding experience. It is this proportion of carbon and silicon which imparts to the product its high modulus and great versatility.

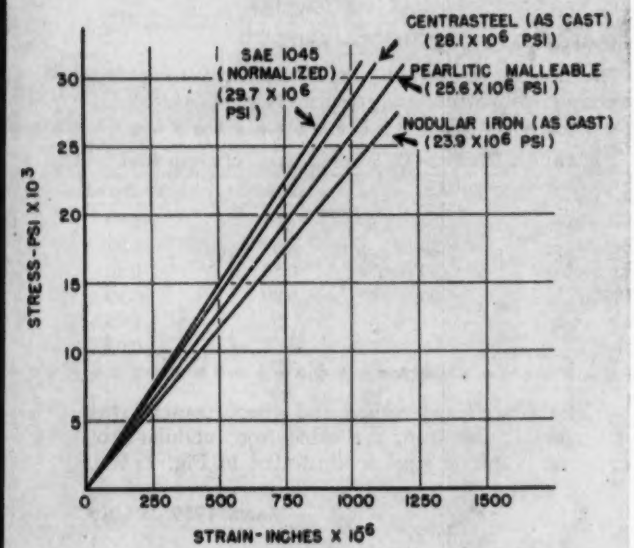
Inoculation of the base metal with a combination of boron and sometimes tellurium or bismuth reacts to produce the compacted graphite structure necessary to obtain high mechanical properties. A typical as-cast microstructure is shown in Fig. 2. All but the eutectoid carbon is present as free graphite having a compacted or roughly spheroidal structure. The matrix is essentially medium to fine pearlite with some "bullseye" ferrite. Graphite is similar to temper carbon but more compact, while usually not being quite as spheroidal as in nodular iron.

The importance of a microstructure free of massive carbide and flake graphite is well recognized in the nodular iron and malleable iron industries. In CentraSteel the optimum boron content, after inoculation, necessary to obtain this condition, is 0.01 per cent boron. It is generally found that the base metal will contain some boron and, therefore, the amount of the inoculant is calculated keeping this fact in mind. Inoculation may be made with a number of boron containing compounds. Among those successfully employed were ferroboron, boron carbide, calcium boride and borax (anhydrous). The tellurium addition giving best results has been 0.005 per cent or less. This may be added as the pure metal, ferrotellurium or copper tellurium.

Additions can be made simultaneously by attachment to a steel rod and plunging into the ladle while tapping from a furnace or transfer ladle. However, in large quantities of metal where considerable turbulence is generated the addition may be placed in the bottom of the receiving ladle or added to the stream.

Tellurium and bismuth may be added to CentraSteel to prevent flake graphite formation in slowly cooled castings. Bismuth in some cases has been found to produce a "lacy" type of flake graphite and for this reason tellurium is preferred.

Fig. 3 . . Stress strain curves showing variation in slope due to differences in elastic modulus.



MECHANICAL PROPERTIES AND HEAT TREATMENT

Evaluation of mechanical properties in both the as-cast and heat treated condition has given sufficient information to suggest a wide scope of applications primarily due to a high value for modulus of elasticity and the susceptibility of the material to various heat treatments.

The absence of hypereutectoid massive carbide and flake-graphite results in useful engineering properties in the as-cast condition. Listed in Table II are as-cast properties of CentraSteel as compared with other cast materials. While ductility is not as high as sometimes obtained in nodular iron, strength is equivalent to both as-cast nodular iron and pearlitic malleable. Moreover, the elastic modulus of 28 million psi, which

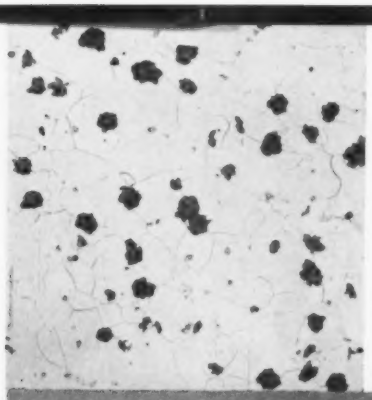


Fig. 4 . . 100% ferritic matrix obtained in 3 hours at 1350 F. Maximum ductility.

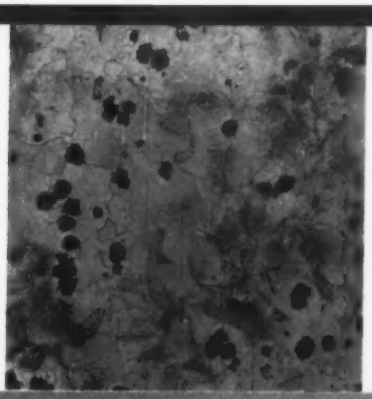


Fig. 5 . . Less pearlite decomposition from 3 hours at 1300 F lowers strength, ductility.

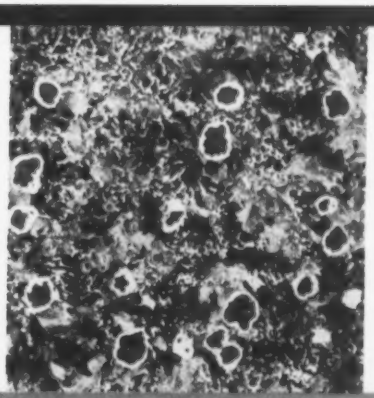


Fig. 6 . . Normalized at 1500 F. Ferrite imparts ductility; pearlite strength.

TABLE II—CentraSteel As-Cast Properties Compared With Other Cast Products

	Tensile Strength (min.) psi	Yield Strength (min.) psi	Elongation In 2 Inches	Modulus Of Elasticity x 10^{-6} (psi)
CentraSteel	80,000	60,000	1-3%	27.5–28.5
Nodular Iron (as-cast)	80,000	60,000	1-10%	20.0–24.0
Pearlitic Malleable	80,000	60,000	1-3%	24.0–26.0

ment in comparison with commercially available materials.

Low temperature stress relief anneals produce an increase in ductility to a minimum of 3 per cent with essentially no effect on tensile strength and no change in microstructure. Minimum time for this treatment is approximately three hours at 1250 F.

Maximum ductility of 15 per cent to 20 per cent with an accompanying decrease in tensile strength to approximately 70,000 psi can be obtained by heating three hours at 1350 F. This is accomplished by decomposition of pearlite to graphite and ferrite. The graphite is deposited onto existing nodules resulting

TABLE III—Mechanical Properties Of Heat Treated CentraSteel As Compared To Other Materials*

	Tensile Strength—1000 Psi						Elongation—% in 2 Inches			
	Min. Ultimate			Min. Yield						Elastic
	Annealed	Normalized[5]	Oil Quench	Annealed	Normalized	Oil Quench	Annealed	Normalized	Oil Quench	Modulus x 10^6 psi
CentraSteel	60[3]	100	120	45[3]	70	90	10-20	2-6	1-5	27.5-28.5
Malleable Iron	50[1]	80	100	32[1]	60[2]	80	10-15[1]	2-3[2]	1-3	24.0-26.0
Nodular Iron	60[3]	100	120	45[3]	70	90	10-25	3-10	1-5	20.0-24.0
SAE 1045 (Wrought)	90[4]	100	120	55[4]	70	80	20-30	15-20	20-25	29.0-30.0

[1]Ferritic Malleable
[2]Pearlitic Malleable
[3]1350F
[4]1450F
[5]1600F
[6]Oil quench from 1600F, tempered 1 hour at 1100F

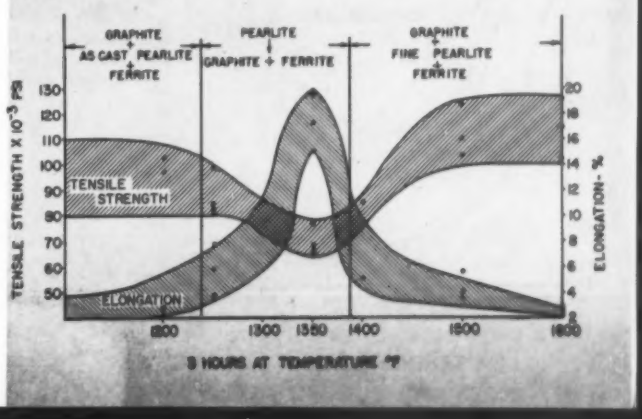
*Tensile bars machined from one inch-square bars after heat treatment

is not altered by heat treatment, is superior to all of the cast iron products and closely approaches the value for steel. This is essentially a function of the quantity of free graphite in the microstructure.

Precise modulus determinations were obtained by a bending beam method using SR-4 strain gages. However, the differences in modulus of various materials is readily discernible by comparison of slopes of stress strain curve as shown in Fig. 3.

Although use of CentraSteel in the as-cast condition is attractive, the material is readily amenable to heat treatment to obtain wide range of properties. Table III shows the properties obtainable from heat treat-

Fig. 7 . . Influence on tensile and ductility of 3 hrs at temperature followed by air cool.



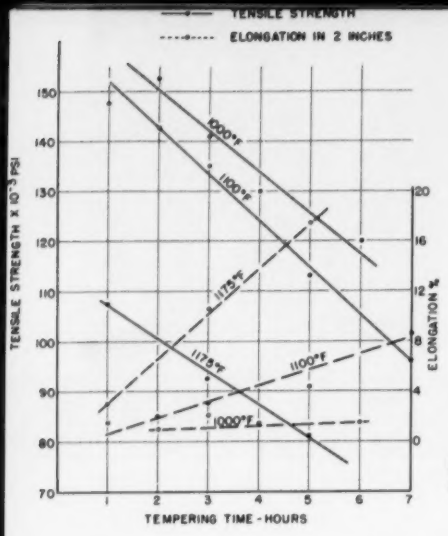


Fig. 8 . . Strength and ductility as function of tempering time and temperature. One in. square bars, oil quenched from 1600 F.

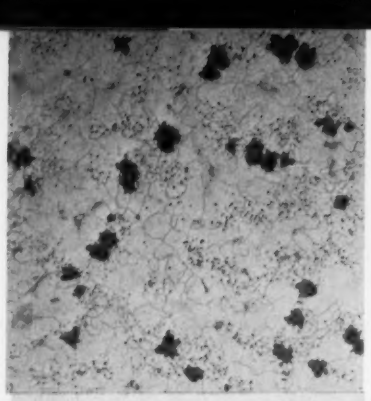


Fig. 9 . . Structure obtained by tempering 8 hrs at 1250 F after oil quench.

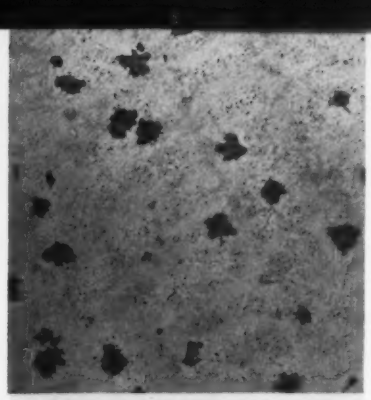


Fig. 10 . . Structure representation 10% elongation by tempering 3 hrs at 1175 F.

in a matrix which is 100 per cent ferritic, Fig. 4. This process is time and temperature dependent and thereby, at lower temperatures the process may be arrested, resulting in considerable ductility with less sacrifice in tensile strength. The effect of the lower temperature anneal on microstructure resulting in partial graphitization of the matrix is illustrated in Fig. 5.

Marked increase in tensile strength is obtained by a normalizing treatment after heating at 1500 F to 1600 F. This treatment produces a refinement of the pearlite resulting in minimum tensile strengths of 100,000 psi. Occurrence of small amounts of ferrite results in an increase in ductility, the amount of which varies inversely with the normalizing temperature, Fig. 6. Tensile strengths as high as 125,000 psi have been obtained by this treatment.

The significant feature of the foregoing heat treatments is the wide range of mechanical properties obtainable in relatively short times at temperature. A graphic illustration of the effects of heat treatment on tensile strength, ductility and microstrucure employing a maximum of three hours at temperature, is shown in Fig. 7.

Maximum mechanical properties are produced in the quenched and tempered condition. Strength and ductility vs. tempering time and temperature is given in Fig. 8. With a tempering temperature of 1100 F it is seen that strength decreases from a maximum of 150,000 psi after one hour to 95,000 psi after seven hours while ductility increases from one per cent to eight per cent. Varying degrees of ductility up to maximum are obtained by reheating in the range of 1000 to 1175 F. By observation of the photomicrographs, Fig. 9 and 10, it is seen that the mechanism here is somewhat different than in the case of annealing from the as-cast condition. Following spheroidization, graphitization of carbides occurs with little or no diffusion of the carbon to existing nodules. Spheroidization of carbides and subsequent decomposition to graphite and ferrite by heating below the critical is apparently much more rapid in the case of the quenched structure than in the case of the as-cast structure.

End quench hardenability curves indicate a slight advantage of CentraSteel over pearlitic malleable and 1045 steel, Fig. 11. Hardenability is greatest in the nodular iron sample represented due, no doubt, to manganese being in solution as a result of low sulfur content.

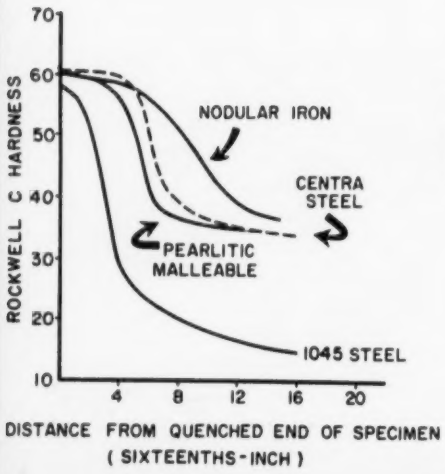


Fig. 11 . . Comparison of representative end quench hardenability curves of various materials.

CHEMICAL AND MICROSTRUCTURAL VARIATIONS

The influence of increased carbon content was investigated from the standpoint of improving castability. Raising carbon content to 2.0 per cent and more, resulted in a corresponding increase in retained carbide. Attempts to eliminate this condition by raising the silicon content or by inoculation with various graphitizers may eliminate carbide, but on so doing, produces type D flake graphite. As in nodular and pearlitic malleable iron, the presence of flake graphite and massive carbide results in a lowering of strength and ductility. However, tensile tests of CentraSteel have indicated that the presence of type D graphite is much more detrimental to mechanical properties than the presence of some small carbides randomly distributed. Acceptable strengths and ductility have been obtained with the presence of as much as 5 per cent carbide (both in the as-cast and heat treated condition) while approximately 5 per cent type D graphite may lower tensile strength by 20,000 psi and reduce ductility to nil. The presence of stubby flake or "quasiflake" graphite in small quantity has essentially no detrimental effects.

Boron retained after inoculation in excess of 0.02

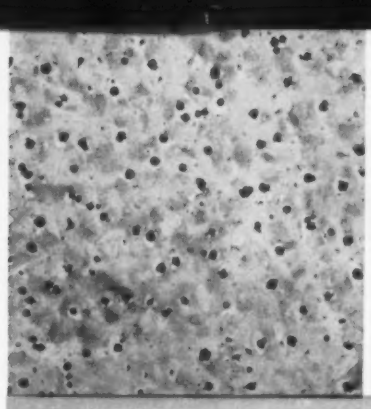


Fig. 12 . . 1/4-in. step plate section showing smaller graphite nodules but no increase in carbide.

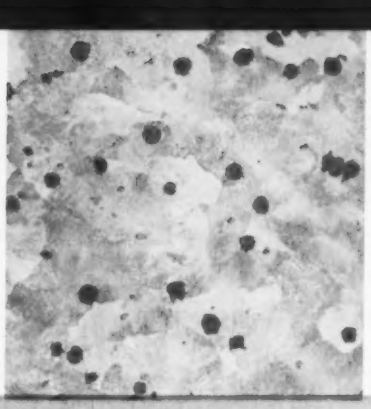


Fig. 14 . . Microstructure of as-cast automotive crankshaft from tensile bar taken from bearing journal section.

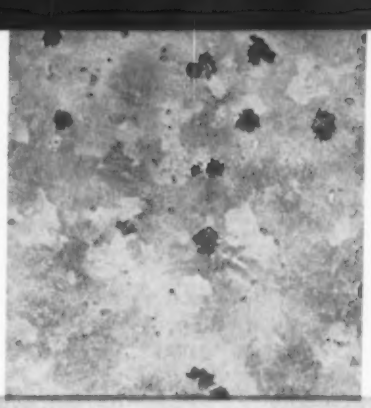


Fig. 15 . . Microstructure of crankshaft normalized at 1600 F from tensile bar taken from bearing journal section.

per cent will result in some stabilized carbide. Therefore, the addition of excess boron does not overcome the deleterious effects of high carbon content. Chemical analysis has indicated that when the preferred, compacted graphite structure is obtained, greater than 90 per cent of the total boron is present as acid insoluble boron while an increasing amount of type D with less compacted graphite is associated with an increase in acid soluble boron.

Although boron is considered to be the ingredient necessary to produce compacted graphite, tellurium is usually added as "insurance" against the formation of flake graphite. No apparent variation in results has been observed with additions of 0.003 per cent to 0.008 per cent tellurium. Tellurium added much in excess of this range produced chill in thin sections. This is of particular interest, since the preferred composition is not highly section sensitive in that there is only slightly greater tendency for carbide in thin sections than in heavy sections.

Manganese is added to combine with sulfur according to the relationship, $\%Mn = 0.3 + (1.7 \times \%S)$. An excess of either manganese or sulfur produces an undesirable carbide stabilizing effect. No limits are, therefore, imposed on the sulfur content providing sufficient manganese is present to assure its formation as manganese sulfide.

MELTING PRACTICE

Laboratory heats were prepared by both high frequency induction and direct arc melting practices. Single heats as large as 2000 lb have been melted by a cupola-direct arc duplexing operation at the Saginaw plant of the Central Foundry Division.

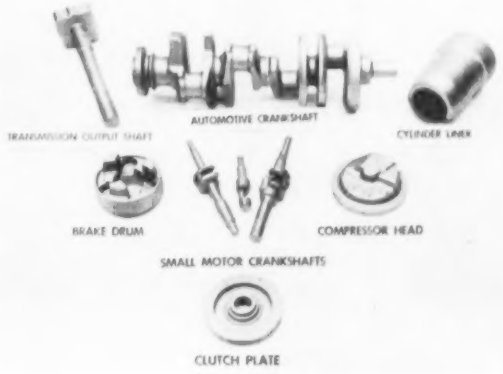
Early investigations indicated that the preferred base composition, without inoculation, solidified in a wide range of microstructures from all gray with flake graphite and some isolated patches of compacted graphite on one extreme, to all white with no free graphite on the other. This initial inconsistency in the uninoculated metal was believed to be the primary cause of varying amounts of residual carbide observed after inoculation. It was suggested that to obtain consistent results subsequent to inoculation, it would be necessary to bring the molten metal for each heat to the same metallurgical condition prior to inoculation. This was accomplished by superheating the base metal at 2900 to 3000 F for a short period of time prior to tapping and inoculation.

In induction melting practice, it was also found that lancing of the melt with any dry gas to produce turbulence considerably reduced the necessary holding time at superheat. Superheating accompanied by turbulence and mixing of the melt, produces a predominance of compacted graphite without separate boron or tellurium inoculation. Subsequent inoculation with boron and tellurium consistently results in microstructures having compacted graphite without flake graphite or massive carbide. The effect gained by gas lancing in the induction furnace could not be obtained by lancing the melt either in the direct arc furnace or in the ladle.

A mechanism by which compacted graphite may be formed was suggested by these investigations. The base iron, being made up primarily of white iron sprue contained 0.001-0.004 per cent boron. Upon superheating and/or lancing to produce compacted graphite without inoculation, the boron was predominantly acid insoluble. If this treatment was not performed and no compacted graphite resulted, the boron was predominantly acid soluble. As mentioned previously the same boron-graphite relationship exists upon inoculation. It appears that the formation of compacted graphite may be associated with the formation of an acid insoluble boron compound which forms more readily at high temperatures. This reaction is no doubt also highly dependent on the nature of the base chemistry and condition of the melt.

Additional observations of interest were made upon vacuum melting. No tendency toward compacted graphite was obtained when the preferred composition was induction melted under low pressures of

Fig. 13 . . Experimental CentreSteel castings.



air or argon. Graphite was type D in a matrix of ferrite and pearlite. Boron was predominantly acid soluble as would be expected from earlier work.

Presumably due to the low cabon content, melting in direct arc often resulted in porosity due to occluded gas. This can be avoided by melting under a protective slag. The 1.80 per cent carbon content is obtained by a mixture of a conventional white iron composition (2.6 per cent carbon, 1.4 per cent silicon, 0.35 per cent manganese, 0.10 per cent sulfur) with plain carbon steel. When melting by induction, white iron sprue is mixed with the steel and melted together.

When melting in a direct arc, the procedure generally followed is to transfer the cupola hot metal to a direct arc furnace followed by addition of the slag. Molten steel, previously melted in a second direct arc furnace, is then mixed with the cupola metal. This procedure enables consistent chemistry control due to minimum oxidation loss, and provides a convenient means of preventing gas pickup. Cold melting by direct arc is also possible but the higher carbon white iron must be melted and a fluid slag obtained prior to addition of steel. In either direct arc or induction melting, silicon and manganese may be added during any stage of the melt.

CASTABILITY

Feeding characteristics of CentraSteel, as might be expected from the low carbon content, are somewhat inferior to white iron of compositions commonly used for malleable iron. However, the actual difference in the two materials is surprisingly small, a condition which is no doubt influenced by the relatively high silicon content of CentraSteel. Sound castings of many varied shapes and sizes have been poured with only slight increases in riser size or minor modifications in gating arrangement to allow for improved feeding in critical areas. In experimental automotive crankshaft castings the cast to clean ratio can be made equal to malleable iron with the addition of small quantities of exothermic riser compound.

Pouring temperatures have been in the range of 2650 to 2750 F, the same as for white iron.

Castings have been produced in green sand, dry sand and shell molds with no apparent variation in results. Of particular significance is the lack of any mottle tendency as often experienced when pouring white iron into shell molds.

The condition of cope side segregation of graphite nodules does not occur in CentraSteel. Homogeneous microstructures are obtained in castings of all sizes.

In most laboratory work with this material, the test casting employed was a step plate which had sections 2 in., 1 in., 1/2-in. and 1/4-in. thick. It was recognized early in the program that there was no greater tendency for carbide to form in the 1/4 in. section, Fig. 12, than the 2-in. section, although size of graphite nodules was reduced.

The lack of "chill" propensity in CentraSteel, unlike both gray and nodular iron, has since become significant, in that castings having wide variations in section size can be produced without the occurrence of

Continued on page 134

1959 CASTINGS CONGRESS PAPERS

■ The technical articles appearing in this preview section of MODERN CASTINGS are the official 1959 AFS Castings Congress papers—the most authoritative technical information available to the metalcasting industry.

Nearly 100 technical papers scheduled for presentation at the 63d Castings Congress of the American Foundrymen's Society at Chicago, April 13-17, 1959, will first be officially preprinted here.

■ Readers planning to participate in oral discussion of these papers during the 63d Castings Congress are advised to bring them to the technical sessions for ready reference.

■ Written discussion of these papers is welcomed and will be included in the publication of the 1959 AFS TRANSACTIONS. Discussions should be submitted to the Technical Department, American Foundrymen's Society, Golf and Wolf Roads, Des Plaines, Ill.

AID FOR THE DESIGN ENGINEER

foundrymen! "accentuate the positive"

By Jules J. Henry

ABSTRACT

The cast process has many advantages over other methods of manufacturing. Calling the designer's attention to these "positive factors" of the cast process will aid him in producing structures and machinery that are stronger, safer and more economical. References are quoted to show the influence of design on the strength of structures and why castings can produce stronger components than other methods. Examples are shown to illustrate the superiority of the cast process, and suggestions are given on how the foundryman can help the design engineer.

INTRODUCTION

For many years, foundrymen have been fighting a battle with wrought metal manufacturers in attempting to prove that cast metals can be as good or even better than wrought metals. Although they must admit that wrought metal test bars can show better physical properties than cast metal test bars of comparable analysis, foundrymen have tried to match test bar values in the attempt to advance the cause of cast metals. It is also true that test bars can be used to evaluate the quality of the metal in a test bar; but here the apparent superiority ends.

Industry does not use test bars to carry loads or build machinery, it uses structures and components. And in these engineered shapes, cast metals can be superior to wrought metals. There has been a growing feeling in industry that test bars do not accurately predict the performance of a structure or component made of the same metal. R. J. Roark has stated "because of the many factors that influence fatigue properties . . . experimental results obtained from conventional tests on small prepared specimens do not provide an altogether satisfactory basis for engineering design."[1]

Caine has also shown that the tension test can overevaluate wrought metals.[2] Even in testing for impact strength, investigators have shown that the standard test specimen is not reliable for evaluating the resistance of structures to shock loads. It is recommended that a notched bar that approximates the size and shape of the component or structure be used, even though it is one developed specifically for the one application.[3] There is a definite trend toward testing full-sized parts under actual stress conditions of service for accurate evaluation of the component itself, as shown in Fig. 1.

Instead of fighting the battle of test bars, foundrymen should band together in a campaign to "accentuate the positive" factors of the cast process. The foundry industry must bring to manufacturers, and particularly to their design engineers, the important fact that the casting process has tremendous advantages of economic importance to give to industry that no other process can duplicate. Some of these advantages are:

1) Design freedom.
2) Reduction of stress concentrations.
3) Low end cost.
4) Uniform strength.
5) Good appearance.
6) Choice of properties.

DESIGN FREEDOM

To the design engineer, this first positive factor can be the most important. It is in this design freedom of the cast process that the design engineer can utilize

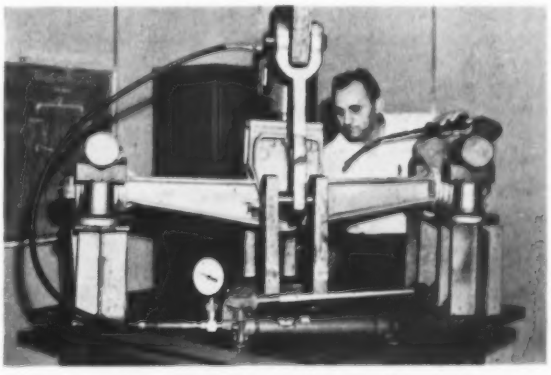


Fig. 1 — Testing of "walking beam" casting with loads simulating actual service conditions.

J. J. HENRY is Prod. Dev. Dir., Missouri Steel Castings Co., Joplin, Mo.

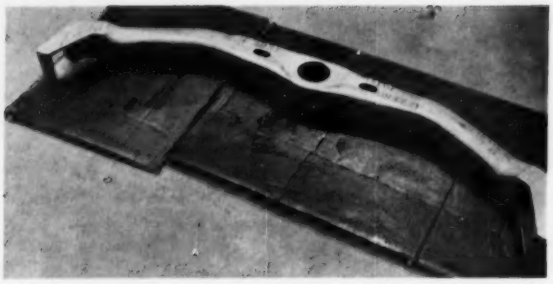


Fig. 2 — (Above) Spring equalizer casting of unusual shape.

Fig. 3 — (Right) Redesign to provide maximum strength at highly stressed areas by using variable sections.

the proper distribution of metal to obtain the optimum weight-strength ratio. In cases where a non-uniform load is applied, it is wasteful to use a uniform standard section just because it is available. An example of this is shown in Fig. 1 which shows the testing of a "walking beam" used on a tandem trailer.

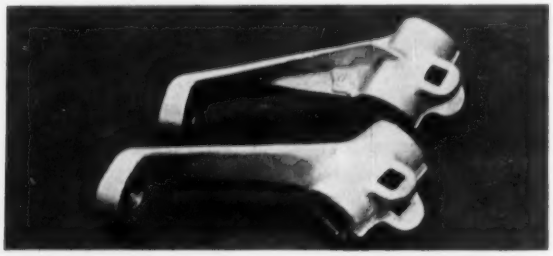


Fig. 4 — Original arm (top) and redesign (bottom).

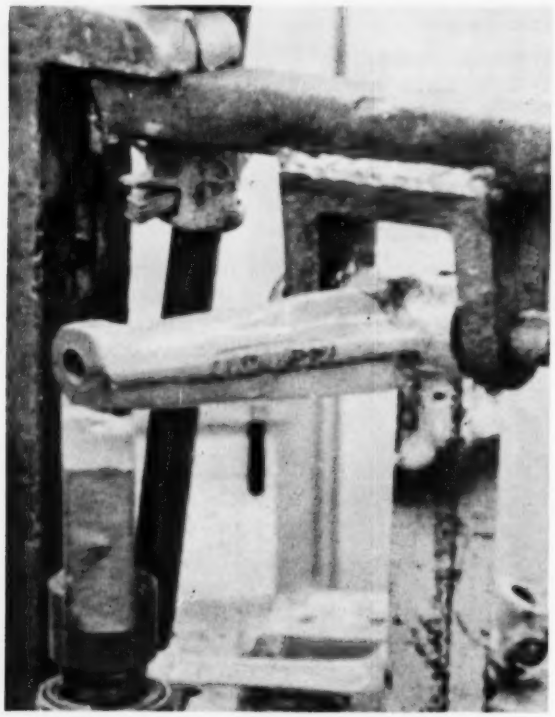
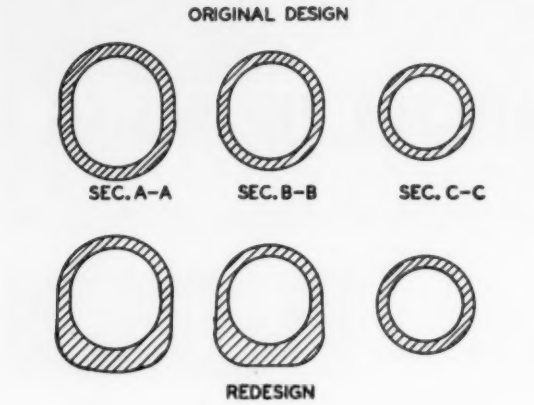
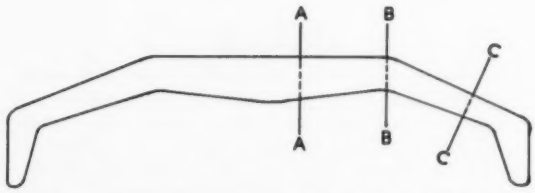


Fig. 5 — Method of loading for stress analysis of original design (Fig. 4).





Loads are applied only at the ends of the bar and at the center. It can easily be seen that maximum strength is needed at the center, so here is where the designer placed the most metal. If the beam were made of a standard rolled shape, it necessarily would be the same size as the center throughout its entire length. The casting process has permitted the designer to place the maximum amount of metal at the place it is most needed. Another example of designing to provide maximum strength at critical stress areas is given in Fig. 2, a spring equalizer used in the trucking industry.

Here again the load is applied only at the ends and center. In this case however, there may be some torsional loads applied, so the structure was made in tubular form. Because of clearance requirements, it was found necessary to bend the two arms. After stress analysis, this structure showed the presence of high stresses at the bends, so it was necessary to redesign these areas to provide the necessary strength. The design freedom of the casting process permitted the designer to use a tube of variable cross-section, as shown in Fig. 3.

The option of the individual in providing thicker sections at stressed areas, and thinner sections at unstressed areas, is a distinct advantage of the casting process that should be brought to the attention of all design engineers.

The casting process by its design freedom, can also allow the designer to utilize special shapes that will offer maximum strength and rigidity per pound of metal. This is illustrated in Fig. 4, which shows the original and the redesign of a machine part that had failed in service. Stress analysis of the casting, as shown in Fig. 5, revealed the maximum stress areas, and the component was redesigned to reduce stresses at these areas and place the metal where it was

needed. Weight of the redesign is the same as the original, but the strength is 50 per cent greater.

There are many references to this factor of design freedom in the literature and many examples have been shown from time to time.[2,4,5,6] This positive factor of the casting process has not been overlooked entirely by design engineers. Some will readily admit that "no other method of manufacture has flexibility in this respect and foundries may well exploit this."[7]

REDUCTION OF STRESS CONCENTRATIONS

This second positive factor is partially dependent on the first one. Indeed, the design freedom inherent in the cast process makes it possible for foundrymen to produce castings with reduced stress concentration areas. By making slight changes in the pattern, one can make larger radii, heavier sections, remove objectional ribs or redesign bosses. These features can all help reduce stress concentrations that are due to design.

Another aspect of the cast process that results in lower stress concentration, is casting a structure in one piece so that joining by welding is not necessary. Welding can induce residual stresses that are sufficient to cause failure, and certainly can contribute to failures at loads much lower than the safe calculated load of the structure.[8] Other causes of residual stresses in fabricated structures or components are forming operations, bending, cold working, permanent or plastic deformation, restraint of deformation, and many others. These are all absent from the casting process.

The fatigue strength of a structure can be influenced by stress concentrations due to design.[9] Sharp corners are known to be areas of high stress concentrations. Eliminations of these high stresses can be difficult in fabricated structures, but can be easily corrected in castings. The theory is illustrated in Fig. 6, which shows the change in stress concentration for a shaft with different sizes of shoulder fillets.[10] It indicates that by changing from a small fillet (r/d = 0.06) to a larger fillet (r/d = 0.20), the stresses can be reduced up to 50 per cent.

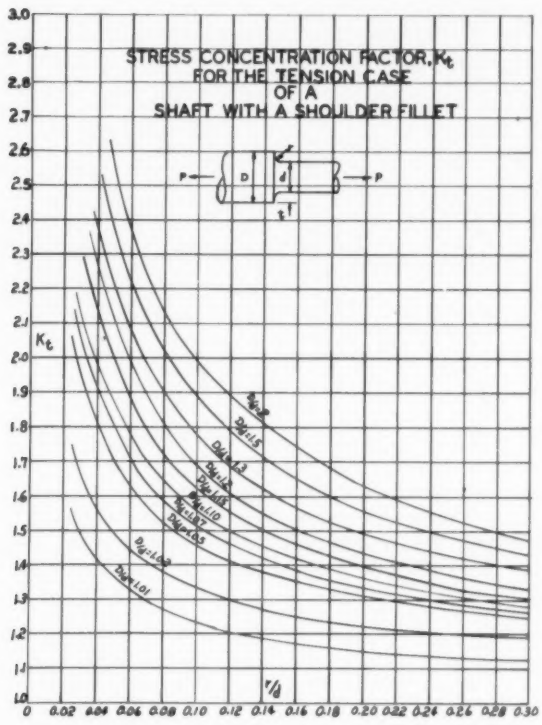


Fig. 6 — Stress concentrations as a function of fillet size (ref. 10).

In a practical case, illustrated in Figs. 7 and 8, the strength of a tractor rail was increased by 30 per cent through reduction of stress concentration by enlarging two fillets. Large radii and streamlined junctions that have low stresses are quite easy to produce in the cast process, but can be difficult if not impossible to fabricate. The optimum junction of two sections for low stresses, shown in Fig. 9, can be produced quite easily by casting, but machining such a junction would be costly and require special tools.

One factor in reduction of stress concentrations that is present in all castings, is the beneficial effect of shot blasting. Investigators have shown significant increases in fatigue strength by shot peening of fabricated surfaces. Comparison of "as received" surfaces

Fig. 7 — Tractor rail casting.

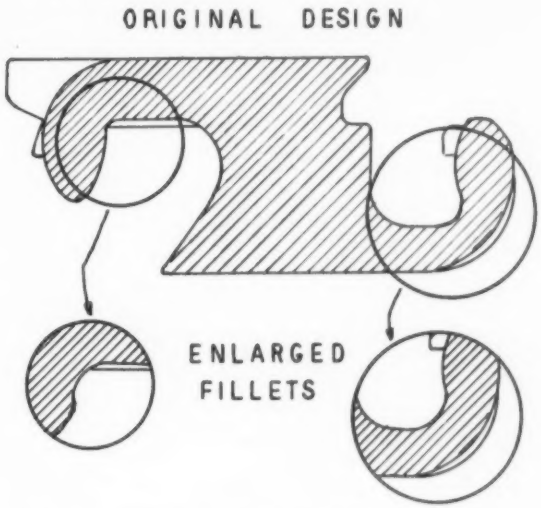
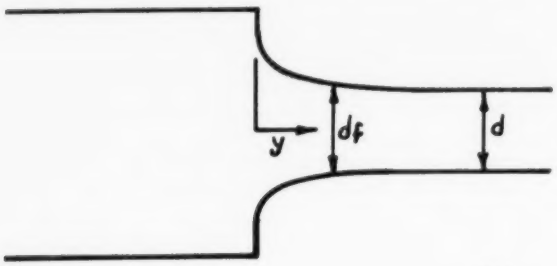


Fig. 8 — Section through tractor rail (Fig. 7) to show areas of stress concentration due to small original fillets.

and polished surfaces, showed that polishing increased the fatigue limit about 20 per cent. Shot peening an as-received finish increased the fatigue limit to the same value as for polished surfaces.[11]

Investigation of residual stresses in structures showed that shot peening increased the endurance limit of steel shafts from 26,000 psi in the polished condition, to 40,000 psi by shot blasting.[12] And this benefit the foundrymen is giving away without cost! Foundrymen: Let us accentuate this positive factor of the casting process to the design engineers.



y/d	df/d for tension	df/d for Bending or torsion	y/d	df/d for tension	df/d for Bending or torsion
0.0	1.636	1.475	0.3	1.187	1.052
0.01	1.572	1.336	0.4	1.134	1.035
0.06	1.440	1.193	0.6	1.070	1.021
0.10	1.374	1.145	0.8	1.037	1.015
0.2	1.260	1.082	1.0	1.019	1.010
			1.6	1.004	1.003

Fig. 9 — Dimensions for optimum shape of radii to provide stress free junctions (ref. 10).

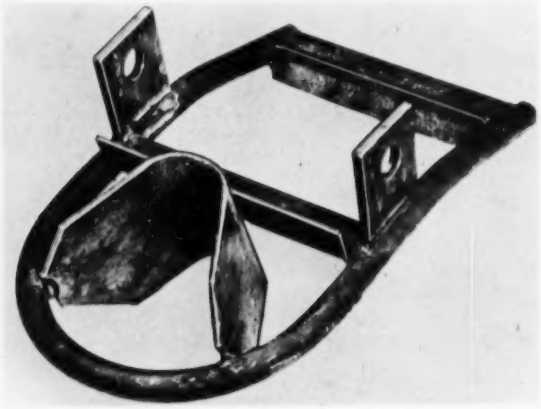


Fig. 10 — Trailer hitch weldment (ref. 4).

Fig. 11 — Trailer hitch casting (ref. 4).

LOW END COST

Many design engineers have been using castings for one reason only, because they are cheap. Foundrymen would rather have design engineers specify castings because they are a quality product that can perform the function desired, at a lower end cost. There is a big difference between cheap castings, and engineered cast structures that are low in end cost. Design engineers are aware of many instances where castings, when substituted for other methods of fabrication, give better performance and yet show savings.

Some examples of these are shown in Figs. 10, 11, 12 and 13, which are taken from Product Development Contests sponsored by the Steel Founders' Society of America. Figures 10 and 11 show replacement of a difficult weldment by a casting with considerable man-hour savings as well as improvement in operation. The casting shown in Fig. 12 showed a unit cost saving of 12 per cent over the weldment shown in Fig.

Fig. 12 — Crawler roller bracket redesigned as casting (ref. 4).

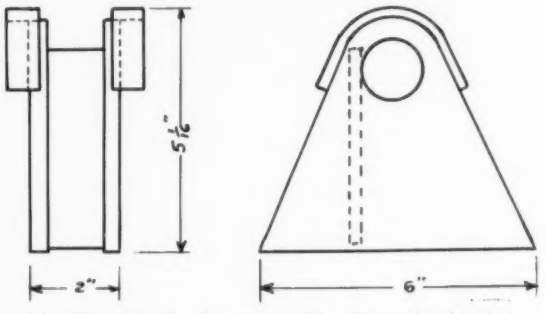


Fig. 13 — Sketch of crawler (Fig. 12) roller bracket as weldment (ref. 4).

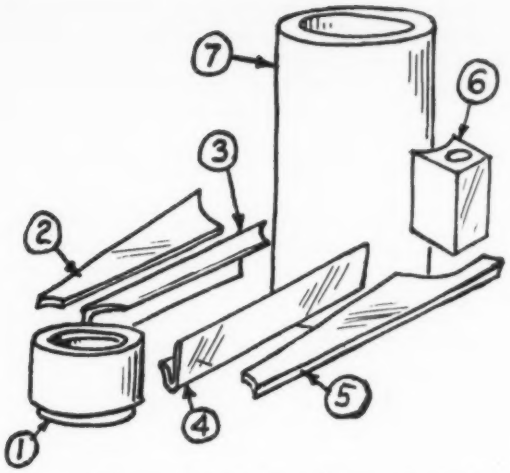


Fig. 14 — Pieces required for weldment of steering arm assembly (ref. 4).

13. In evaluating the end cost of a casting, all items must come under consideration.

The cost of the weldment in Fig. 14 was given as

Total material cost	$19.28
Welding cost	5.80
Fabricating charges	3.10
Total estimated cost	$28.18

While the cost of the casting shown in Fig. 15 was

Cast steel casting	$27.20
Handling costs	2.72
	$29.92

which appears to be higher than the weldment. But a further break down of other savings possible with a casting shows the elimination of:

16 purchasing operations.
20 receiving operations.
16 stores operations.
42 materials handling operations.
10 fabricating operations.
1 machining operation.
22 inspection operations.

Total 128 operations eliminated.

Which do you now think had the lower end cost? This then is another positive factor of the cast process: elimination of indirect labor.

UNIFORM STRENGTH

This positive factor available in the casting process at no extra cost, is one that is frequently overlooked by the design engineers. All too frequently they are influenced by the higher test bar results of other fabricating methods, without realizing that there can be considerable difference in some of the physical properties depending on the direction of rolling or forging, as the case may be.

This difference is particularly true in tensile ductility values. It is possible for the transverse direction to have one-half the value of the longitudinal direction. It has also been shown that the directionality, or anisotropic effect, for wrought steels can influence the toughness in the impact test as shown in Table 1.[13]

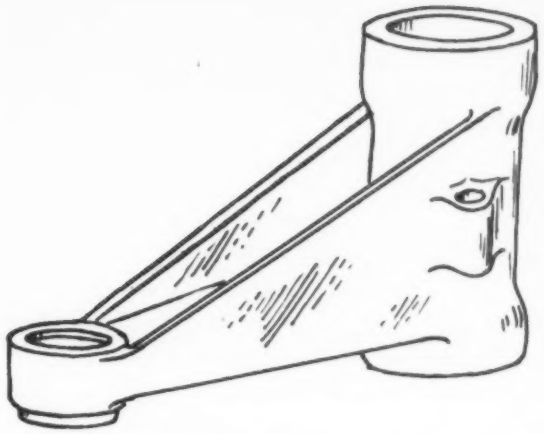


Fig. 15 — Steering arm assembly as a cast steel kingpin (ref. 4).

Foundrymen have not emphasized to the design engineer this beneficial crystal structure of the cast process. Multi-directional properties can be beneficial in structures such as gears, where equal strength in all directions is a design necessity. Fabricating gears out of a rolled plate is certain to produce teeth of varying abilities to withstand shock, impact, fatigue, etc., because of the anisotropic effect of wrought metals.

In the case of steel castings, and probably in some nonferrous castings, heat treatments are normally part of the process and so insure the absence of residual stresses that are present in most wrought metals. Here again foundrymen have been giving to design engineers stress relieving as a part of the cast process, which other processes include as an extra charge.

GOOD APPEARANCE

Streamlining. Need more be said for good appearance? Structures certainly look stronger, actually are stronger, have more eye appeal and are easier to sell when streamlined. Foundrymen should realize that full utilization of streamlining will not only please the design engineer, but also make his own job easier. Smooth flowing lines, gradual section changes, absence of abrupt corners or angles, all result in castings that are easier to produce. So, in selling this positive factor to the design engineer, the foundryman is actually helping himself.

Also, it must be brought to the attention of the design engineer that the casting process can make

TABLE 1 — TENSILE, HARDNESS AND FATIGUE TEST RESULTS FOR WROUGHT 4140 STEEL

Direction	Tensile Strength, psi	Yield Strength, psi	Red. of Area, %	Elongation, %
Transverse	110,700	81,000	29.5	13.0
Longitudinal	110,100	80,400	60.0	24.5

	Endurance Limit, psi		Endurance Ratio	
	Unnotched	Notched	Unnotched	Notched
Transverse	53,000	26,000	0.48	0.24
Longitudinal	61,000	28,000	0.55	0.25

TABLE 2 — RANGE OF PROPERTIES OF CAST METALS

	Tensile Strength, psi	Modulus of Elasticity	Hardness, Bhn
Gray iron	15,000 — 75,000	9 — 20 × 10^6	170 — 400
Nodular iron	58,000 — 150,000	18 — 25 × 10^6	140 — 400
Malleable iron	50,000 — 90,000	25 — 28 × 10^6	110 — 285
Steel	55,000 — 250,000	29 — 30 × 10^6	120 — 550
Aluminum and alloys	13,000 — 50,000	10 — 11 × 10^6	40 — 140
Copper and alloys	30,000 — 165,000	9 — 10 × 10^6	40 — 235
Magnesium and alloys	26,000 — 49,000	6 × 10^6	50 — 80
Nickel and alloys	55,000 — 285,000	21 — 31 × 10^6	90 — 350

streamlined structures much easier and much more economically than any other process. Only the forging process, of all the other manufacturing methods, can approach the cast process in ease of producing well streamlined structures. Reference to most of the preceeding photographs certainly emphasizes the better appearance of castings.

CHOICE OF PHYSICAL PROPERTIES

This factor is not one of the major advantages of the cast process, since other methods can offer a great variety of physical properties at an extra cost, if the quantities are sufficiently large. The cast process, however, can offer a much greater choice even in small quantities if needed. A great variety of chemical analyses can be procured from producers of castings in all types of metals.

Mechanical properties in the ranges given in Table 2 are available.

This list is by no means complete, for added to this can be the metals specially developed to resist corrosion, heat shock, abrasion, creep, to mention only a few. Also, design engineers should know about the many special metals that can not be wrought, and must be made in the final shape by the cast process.

Foundrymen: you have so many positives to accentuate about the cast process that it is difficult to put an end to the imposing list.

AIDS FOR THE DESIGNER

Let us discuss a few specific ways that the foundryman can offer positive help to the design engineer. In the matter of design freedom, foundrymen can help the design engineer by suggesting ways to improve the design while it is in the development stage. This is not always easy, since many design engineers are behind an iron curtain created by purchasing agents. But it is possible to have meetings with engineers on design problems, in fact there are some foundries who have scheduled casting design clinics to which they have invited their customers' engineers.

This is a potent method of demonstrating the design freedom inherent in the cast process to the persons who will actually be using it. Figures 16, 17 and 18 illustrate some of the many complex designs that can be shown to design engineers as examples of design freedom.

Caine has stated that one of the greatest increases in casting usage can be created by supplying the design engineer with information on the properties of irregular sections.[15] There are many tables giving properties of regular sections, published by wrought metal manufacturers, and these are within reach of every design engineer. So it is too convenient for

Fig. 16 — (Above) Cast steel compressor cylinder (ref. 4).

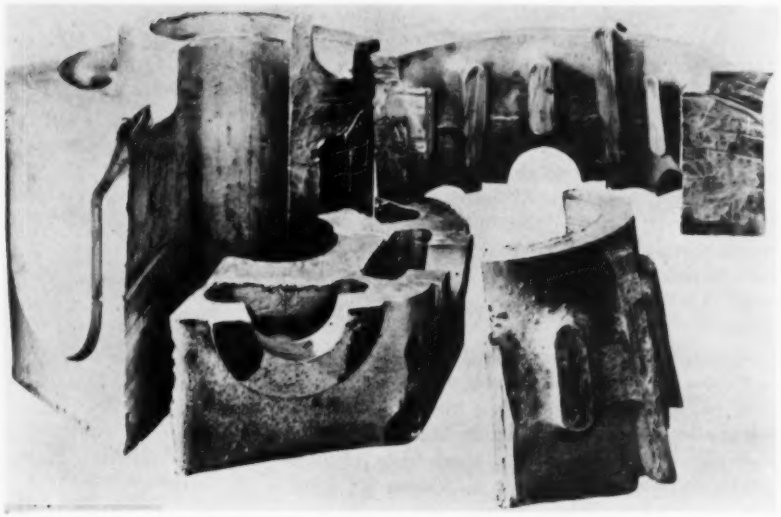


Fig. 17 — (Right) Compressor sectioned to show complex internal structure (ref. 4).

him to pick up a handbook that contains all the information that he needs, in designing a wrought structure. But if he can use irregular sections to better advantage, unfortunately it becomes necessary for him to calculate all the properties in question.

Foundrymen: you should provide the design engineer with this information. Perhaps handbooks prepared by the various national foundry organizations may be the answer. This means of course, that foundrymen must become familiar with the terms used by design engineers. While it is not necessary to be a mechanical engineer in order to understand the meaning of Youngs Modulus, one must become familiar with commonly used design terms, such as central axis, fiber stress, neutral axis, moment of inertia, unit stress, etc.

Just understanding their terms and language will help appreciably in dealing with design engineers. Therefore, one important item in aiding him is to provide technical information showing properties of irregular shapes that can be used to obtain the best weight-strength ratio in his design.

Another rather new area for the foundryman to probe in helping the design engineer, is to investigate stress concentrations. Establishment of a stress analysis laboratory by casting producers may seem to be a little beyond the normal scope of foundry operations. However, closer examination of this new field will show that foundries are the most logical location for stress analysis laboratories. Foundries are normally dealing with hundreds of different designs each year, while a manufacturer of machinery or other equipment may have a new design only once a year.

For a small manufacturer a stress analysis laboratory is practically out of the question, yet he can gain appreciable benefits from a stress analysis of his designs. Of course, that does not mean that foundries should do the original design work, but they ought to be in a position where they are able to check their customers' designs for unforseen stress concentrations. This is exemplified in Fig. 19, which pointed out stress concentration areas to the design engineer. These stresses were substantially reduced, as shown in Fig. 20.

Lower end cost of castings can also be an area where foundrymen can offer valuable assistance to the designer. Here again, the use of a stress analysis laboratory can be of great value in revealing areas where weight can be safely reduced. Also the use of cores and uneven partings (which the foundryman would rather not see in castings) can, in many cases, reduce the end cost by decreasing weight or eliminating machining. Some foundrymen have been guilty of forcing simplification of the design in order to obtain as much weight as possible, without regard to the final end cost to the customer.

This is a short-sighted attitude, since simple masses of metal are easier and cheaper to produce by other methods and will eventually be lost by the foundry industry anyway. The intelligent approach is to help the design engineer reduce his end cost by making the structure in the most economical way, and in a shape that no other method can successfully duplicate. Remember that complex shapes, with cores and variable sections, can only be produced by the cast process. The designs, illustrated in Figs. 2, 7 and 16, show castings that can not be produced in any other way without excessive cost.

Fig. 18 — Suction nozzle end head for barrel pump (ref. 4).

Uniform strength that is inherent in the cast process, is dependent on the foundryman's individual concept of quality. Consistent analyses and heat treating, together with the absence of surface defects in stressed areas, will assure the design engineer of obtaining the anticipated strength in his structure.

One of the most outspoken adherents of better appearance in castings has been Clyde Sanders, who has

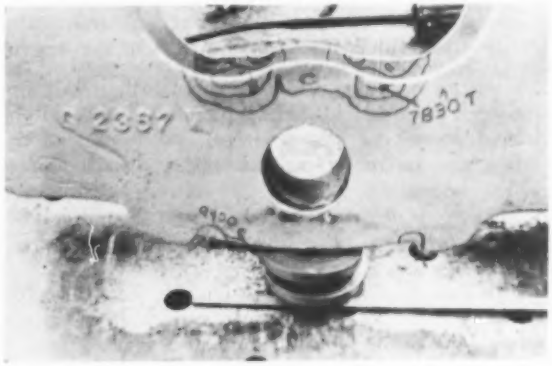


Fig. 19 — Spring equalizer, showing stress concentration areas.

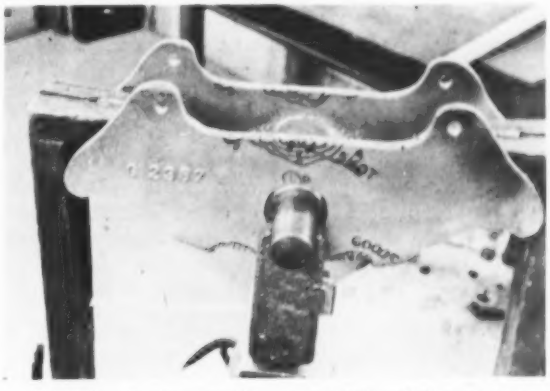


Fig. 20 — Spring equalizer, suggested redesign to reduce stress concentrations.

repeatedly urged foundrymen to use finer sands and closer sand control to improve surface finishes.[16] One of the best ways to turn a design engineer away from castings is to have a roughly finished, poorly cleaned casting in a prominent place on his machinery. Foundrymen can help the design engineer by finding out which surfaces are important in regard to appearance, and then take more effort to make the engineer proud of his accomplishment.

Data sheets of the various alloys and physical properties of the metals produced by each foundry can be of considerable aid to the design engineer. Quite frequently the design engineer may not specify the best alloy for a particular design, simply because he was not aware of the great variety of physical properties the foundry can produce. Cooperation with the designer in selecting the proper alloy or heat treatment is beneficial to the foundry, as well as to the design engineer.

As a final suggestion, think of the wonderful mutual benefits that could result from the foundryman receiving information on static and dynamic stresses, their direction and magnitude, on all drawings for all customers' designs.

SUMMARY

The foundryman has much in the cast process to recommend to the design engineer. Calling his attention to the positive factors of the cast process will aid him in producing structures and machinery that are safer, stronger and more economical. Some of the beneficial factors of the cast process and methods that the foundryman can use to help the design engineers are:

1) *Design freedom.* Provide tables containing information on the properties of irregular sections that can be most economically produced by the cast process.
2) *Reduction of stress concentrations.* Install stress laboratories in order to evaluate designs for possible high stress areas.
3) *Low end cost.* Demonstrate how castings can provide the best weight-strength ratio and eliminate some machining, joining and handling.
4) *Uniform strength.* Install quality control methods, and give particular attention to highly stressed areas.
5) *Improved appearance.* Use best materials and methods available to produce smooth castings with streamlined features.
6) *Choice of properties.* Provide design engineers with data on types of metal produced, and methods of obtaining variations in physical properties.

REFERENCES

1. R. J. Roark, *Formulas for Stress and Strain*, McGraw-Hill, New York, p. 42, 1954.
2. J. B. Caine, "The Case Against the Tension Test," *Foundry*, Nov. 1957 and Sept. 1958.
3. S. L. Hoyt, "Notched-Bar Testing, Theory and Practice," *Symposium on Impact Testing*, A. S. T. M., p. 5, 1955.
4. Product Development Contest Bulletins 1954, 1956, Steel Founders' Society of America.
5. S. C. Massari, "Marketing Your Product," AFS Transactions, *vol. 64*, p. 1, 1956.
6. J. M. Tarnow, "What the Designer Should Know About Production — Part 3," *Machinery*, Nov. 1958.
7. T. Davidson, "What Design Engineers Look for in Castings," AFS Transactions, *vol. 63*, p. 282, 1955.
8. L. E. Benson, "Some Considerations Regarding the Generation and Importance of Residual Welding Stresses," *Residual Stresses in Metals and Metal Construction*, Reinhold Publishing Corp., New York, p. 76, 1954.
9. W. T. Bean, Jr., "Endurance — A Criterion of Design," *Symposium on Testing of Parts and Assemblies*, A. S. T. M. Technical Publication 72.
10. R. E. Peterson, *Stress Concentration Design Factors*, John Wiley & Sons, Inc., New York, p. 65-67, 1953.
11. R. P. Felgar, "Effect of Shot Peening on Fatigue Strength," A. S. M. E. Paper No. 58-SA-46, p. 1, 1958.
12. O. J. Horger and H. R. Neifert, "Correlation of Residual Stresses with Fatigue Strength of Machine Elements and Related Phenomena," *Residual Stresses in Metals and Metal Construction*, Reinhold Publishing Corp., New York, p. 248, 1954.
13. E. B. Evans, S. J. Ebert, C. W. Briggs, "Fatigue Properties of Cast and Comparable Wrought Steels," A. S. T. M. *Proceedings*, p. 14, 1956.
14. "Properties of Materials," *Materials in Design Engineering*, p. 30-123, Oct. 1958.
15. J. B. Caine, "How To Deal With Customers Engineers", Talk given at Div. VII, Steel Founders' Society of America Meeting, Sept. 5, 1958.
16. C. A. Sanders, "Casting Finish — Tolerance — Precision," AFS Transactions, *v. 64*, p. 318, 1956.

HOW AIRCRAFT DESIGNERS LOOK AT LIGHT METAL CASTINGS

By Albert R. Mead

ABSTRACT

Light-metal castings could be used in modern aircraft design more than they are at the present time if they can be developed to the point where they meet strength requirements of 60 ksi ultimate strength, 50 ksi yield strength and 5 per cent elongation, in the author's opinion.

Flight loads which must be considered in aircraft design are:

1) Maneuver loads.
2) Gust loads.
3) Flutter.
4) Pressurization loads.
5) Power plant loads.
6) Sonic fatigue.

Besides these flight loads, nonflight loads must also be considered. Those which are considered are for carrier-based aircraft.

The problems with various light-metal alloys in the manufacture of aircraft are considered.

INTRODUCTION

As a prime contractor for the U.S. Navy, the author's company is responsible for the design and manufacture of Naval aircraft. The company is awarded a contract by the contracting agency after a review of a design proposal, which is essentially a detailed specification and basic drawings. The contract or letter of intent will include the items to be produced and the information required, such as analyses, drawings and tests.

The detailed specifications prepared according to the latest issue of a General Specification for the design and construction of airplanes for the U.S. Navy. When a contract or letter of intent has been received the engineering team goes to work calculating the strength required for catapulting, arrested landings, flight loads, nonflight loads, hoisting, tanks, fasteners, materials, etc.

Now that the general outline of the aircraft is fixed, weight, proper strength, ease of manufacture, reliability, ease of servicing and many other factors too numerous to mention become of importance.

An example of how weight is of prime importance is exemplified by this information.

The approximate effect of an additional 100 lb over design weight on performance for a swept wing Naval fighter is:

Max. speed	= −1 knot
Combat radius	= −2 miles
Combat ceiling (500 ft/min R/climb)	= −120 ft
Rate of climb	= −160 ft/min

A. R. MEAD is Engr., Grumman Aircraft Engrg. Corp., Bethpage, N.Y.

Ease of manufacture and cost of production come into play early in design, and here is where the designer considers light metal castings. However, before light metal castings are discussed in detail some of the loads which must be considered in the design of an aircraft will be presented.

LOAD DESIGN CONSIDERATIONS

Maneuver Loads. When an airplane is flying level, the intensity of the vertical pressure on the wings is just sufficient to balance the weight of the airplane. If the aircraft deviates from level flight and takes a curvilinear course, the balance is interrupted and an acceleration results. The resultant accelerations cause loads which must be considered in design. The strains induced on the structure due to other than level flight are related in a linear manner to the accelerations of the aircraft as measured at the center of gravity.

Gust Loads. Along with maneuver loads, gust loads must be evaluated. A simple way of presenting gust statistics is to indicate the number of times a particular gust velocity is exceeded in a certain flight path. High altitude gust loads are much less severe than ground level gust loads.

As many as 10 gusts may be encountered in each mile of flight. Flutter must be considered, but here a basic definition of flutter is in order because of the complexities of this phenomenon, the author believes.

Flutter. This is a self-excited oscillation of a structural part resulting from a combination of inertia, elastic, aerodynamic, damping and temperature forces. In combination these forces can result in unstable motion of the structural part, not the airplane, (i.e. flutter) which leads to mild or extremely severe structural failures. Flutter is usually restricted to control surfaces, etc.

Pressurization Loads. These must be considered due to the rather large loads produced in cockpit and fuselage areas from pressure differentials (between pressurized cockpit and outside air). Pressurization loads have caused some much publicized serious crashes in foreign aircraft.

Power Plant Loads. These are important especially when any vibration is present, and are thoroughly checked by Engineering personnel.

Sonic Fatigue. This is another type load which has

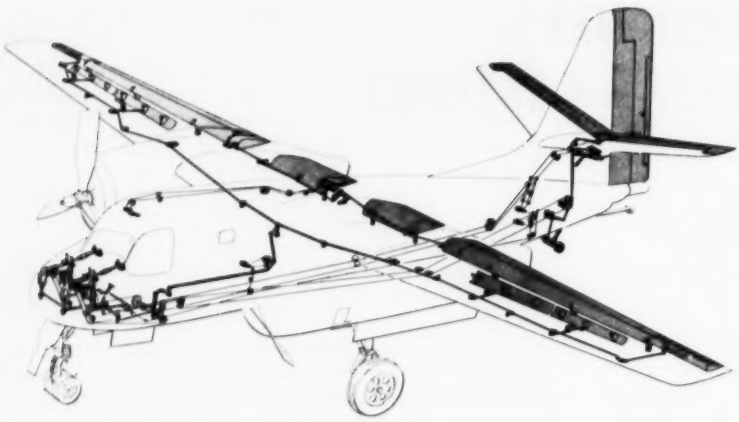


Fig. 1 — An example of one system in a modern aircraft where castings were selected for use. Most of the castings are used in the controls system.

caused serious problems, especially in jet aircraft. High frequency noise impinging on aircraft structure must be either eliminated or the structure must be sufficiently strong to withstand the loads created by the noise.

The flight loads mentioned are of prime importance, but we also should mention the nonflight loads which cause the designer and stress analyst considerable concern. Since the author's company builds a large number of carrier-based aircraft, these will be concentrated on. They include:

1) High sink speeds associated with arrested landings (over 23 ft/sec).
2) Towing loads which often times are much higher than those of land-based planes.
3) Securing loads. High loads can result due to high wind-over-deck velocities.
4) Hoisting requirements for frequent and rapid hoisting cause high loads on structure and hoisting attachment areas.
5) Catapulting. Large loads due to rapid accelerations in catapult take-offs place much importance on this load criteria (approx. 4G loads).
6) Arresting. Large loads, which the airplane is subjected to in arrested landings, play a major role in designing carrier-based aircraft. Consideration must be given to arrested landings at maximum gross weight due to emergency arrestations.
7) Wing folding loads are not severe when the folding takes place in a hangar, but on board the carrier with high wind-over-deck velocities, wing folding loads are high.
8) Crash loads. High loads which are developed when an arresting hook or cable breaks and the airplane goes into the barricade must be accounted for in design.

A few other loading conditions that exist for carrier-based aircraft are considered, but they will not be considered in detail here.

After due consideration is given to the loads previously mentioned, the designer goes to work to see where he might combine bits and pieces into one piece of structure (if this proves economical). Here is where casting is considered as a possible process for making parts. An excellent example of one system in a modern aircraft where castings were selected is in one of the company's airplanes. Most of these castings are used in the controls system as bellcranks, as illustrated in Fig. 1.

When this airplane was first considered, a serious lack of machine time was evident on the eastern coast of the U.S. because of the mobilization in progress due to the Korean War. The airplane had many bellcranks, arms, etc., which could be made into castings, so a detailed engineering investigation was started to make full use of castings.

Castings have been used for many years in all industries for three major reasons:

1) Low cost—tooling costs (dies vs. patterns) are much lower, and small quantities can be made economically.
2) Intricate shapes can be made which are not possible by any other process.
3) No wide differential between transverse and longitudinal properties exists in castings as can exist with forgings, extrusions and rolled shapes.

AIRCRAFT CASTING USE

Control system castings are often designed on a stiffness basis, and as a result the stresses in these parts were comparatively low. This was a point in favor of the castings since the design allowables for castings available in the early 1950's were:

	220-T4	356-T6
F_{tu}	42,000 psi	30,000
% Elong.	12	3

220-T4 was first selected because of the 40 per cent higher ultimate tensile strength. After the many parts were properly designed, the production lots of 220-T4 castings were received and serious inconsistencies in quality were found.

In order to insure a fair x-ray standard for acceptance of production parts, the following procedure was used to arrive at a realistic quality control.

1) Select the three poorest looking x-ray prints from the first production lot of castings which pass the minimum x-ray soundness standards based on experience and specifications.

2) Machine the three parts selected under (1) to finished dimensions, then re-x-ray and statically test to failure. The loading duplicates service conditions.
3) If the static failing loads are satisfactory after engineering evaluation, the x-rays for the three castings tested would then be used as a minimum x-ray acceptance standard.

This inspection standard served initially to accept castings for production airplanes. As production rates increased, the number of rejected parts increased considerably. A thorough cost evaluation was made and the high cost of rejections, etc., caused management concern. As production increased, quality control by the producing foundries decreased, so it became necessary to re-evaluate the company's position.

About this time American-Brake Shoe Co. of Mahwah, N.J., requested that the company work with them on a joint high integrity casting program in order to develop high strength reliable aircraft castings. This work is described in the February 17, 1958 issue of *Product Engineering*.

For general information, the stress at 100 per cent limit load (the highest load expected in the service life of the aircraft) was calculated as follows: the critical stress at 100 per cent limit load was defined as 14,400 psi. This value was arrived at by dividing a factor of 1.3 into 75 per cent of yield stress of the alloy being considered. (In the original design, the values of 220-T4 were used.) The specified minimum tensile strength for 220-T4 was 42,000 psi with a typical yield strength of 25,000 psi.

A few shortcomings of specifications were resolved due to the work of many foundry and aircraft materials people, who found that most aircraft designers were reluctant to use castings in large numbers because wide variation in strength and soundness from casting to casting was evident, and a higher level of strength could be obtained with wrought materials. In addition, loose specifications permitting a large differential between test bar and casting properties make the use of a large casting factor necessary. All three factors tend to increase the weight of the part. Increased use of castings in the aircraft field would occur if uniform and consistent high strength castings were available.

Two factors in existing specifications which cause concern are:

1) Separately cast test bars vs. test bars cut from castings.
2) Lack of correlation between x-ray properties and mechanical properties.

Both problems have an important bearing on the thinking of design engineers with regard to the use of castings.

CUT TEST BARS FROM CASTINGS

Aluminum aircraft castings are commonly produced in conformance with Federal Specification QQ-A-601 and MIL-C-6021B. These specifications dictate that, after heat treatment, a separately cast standard 0.505 in. diameter test bar of 356-T6 shall possess mechanical properties of 20,000 psi yield strength, 30,000 psi tensile strength and 3 per cent elongation. However, these specifications permit the average of three test bars cut from the castings be as low as 20,000 psi yield strength, 22,500 psi tensile and ¾ per cent elongation. Under these specifications, one or more bars could have zero per cent elongation, so long as the average is ¾ per cent.

The designer, unfortunately, is using the casting and not the test bar. Now however, the new specification for high strength aluminum alloys (MIL-C-21180A) is a major step forward in overcoming some of these problems.

On one aircraft the author's company uses several light metal castings as well as a few ferrous castings. The most complex castings are made from magnesium alloy AZ63, and make up the slat core (a slat is used to create a flow over the airfoil which in turn lowers the stall speed of the aircraft). This is important for high speed, carrier-based aircraft. Other planes in the same speed range of this airplane require long runways or a tail chute when landing. An aluminum alloy skin is put on the aerodynamic side of this part, and a magnesium sheet on the inside (where magnesium is used 5056 rivets are put in), and care taken to properly insulate all joints involving dissimilar metals. The casting method of manufacture saved a large sum of money for this particular assembly.

Alternate methods of manufacture were:

1) Bits and pieces.
2) Complete casting (core and skins).
3) Honey comb.

Figure 2 shows two of the alternate types of manufacture.

The honeycomb structure was the lightest, but was expensive to manufacture. The complete casting was also expensive, and it was difficult to protect against rain erosion.

Castings are often considered as replacements for welded structure. Figure 3 shows a welded steel jato rack (for an amphibian) which was replaced by a casting. The jato system was incorporated in this aircraft to help shorten take-off runs with large loads

Fig. 2 — Two of the alternate types of manufacture for a slat core. Top — the honeycomb structure, which although is lightest is expensive to manufacture. Bottom — the complete casting (core and skins) which is difficult to protect against rain erosion.

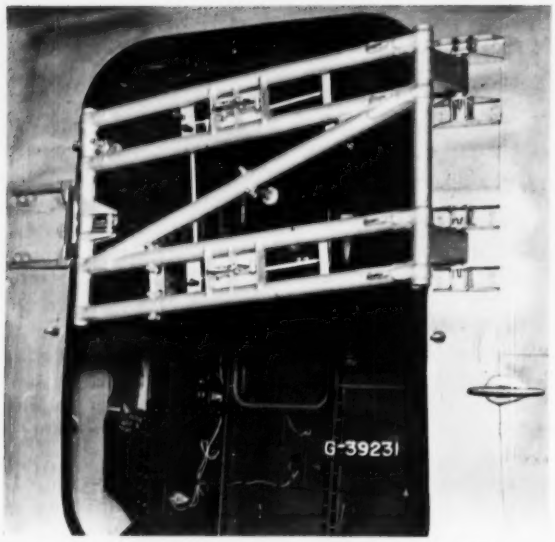


Fig. 3 — A welded steel jato rack for an amphibian which was replaced by a casting.

aboard, help take-off in rough seas, help take-off from ice covered runways (some of these airplanes are triphibians) and to help steer the airplane in high winds.

The addition of the jato system has helped immeasurably in the performance of the main mission of this aircraft, i.e., air sea rescue.

The initial weldments of normalized 4130 steel were satisfactory from a strength standpoint. However, manufacture was difficult due to warpage, so a casting was designed for a magnesium alloy. Then the magnesium alloy casting was changed to 356-T6 before the first production castings were made. There has been no service problems with this part to date.

On one of the company's airplanes, the trailer was an application for a rather heavy set of load distributing links which were originally considered as either a steel weldment or a steel casting. Due to the design concept of this light weight trailer, aircraft thinking in regard to weight and high efficiency of construction materials were paramount. The two castings, shown in Fig. 5, were first manufactured from 356-T6 alloy, but due to the close design philosophy (i.e., small casting factor) the static tests on these parts were so marginal that an alloy change was made to Al Mag-35 (used in the as-cast condition). The extra strength and better ductility of this alloy enabled the static test to be successfully completed. An interesting point should be made here which might prove helpful in the future. If cooling from the casting temperature of Al Mag-35 is improperly controlled, a two-phase microstructure will result which will be responsible for a loss in yield strength and ductility.

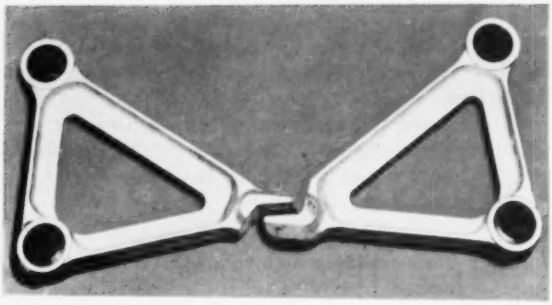


Fig. 5 — Trailer castings.

Recent aircraft industry problems relating to aluminum-magnesium Alloy 220 have resulted in the issuance of official letter from the Bureau of Aeronautics requesting the number and position of all 220 alloy castings in airplanes produced during the last 5 years. This does not mean to give the 220 casting alloy a black eye, for this alloy has potential use, but careful consideration must be given to any sustained stress applications. In 220 casting alloys the aluminum-magnesium constituent is highly anodic to both aluminum and the aluminum-magnesium solid solution. Attempts to overcome this shortcoming required additions of manganese and chromium in small amounts. Most of the cases of partial and complete failure reported to date were caused by two major and one minor factors. They are:

1) Applications which made possible the over-stressing of parts: To be specific, 95 per cent of the trouble occurred when bolts were used to attach rod end bearings to ears on the castings. Bolts were inserted and a specified torque was given to personnel putting together the assemblies. If care was not taken even with the use of torque wrenches, it was easy to over-torque the bolts, and thus, high sustained stresses caused failure by stress corrosion. (These overstressed areas were also aggravated by fatigue and operating loads.)
2) Pressed in bushings and bearings: Due to manufacturing tolerances, etc., high interference fits caused a few cases of this type of high sustained stress which ultimately led to failure.

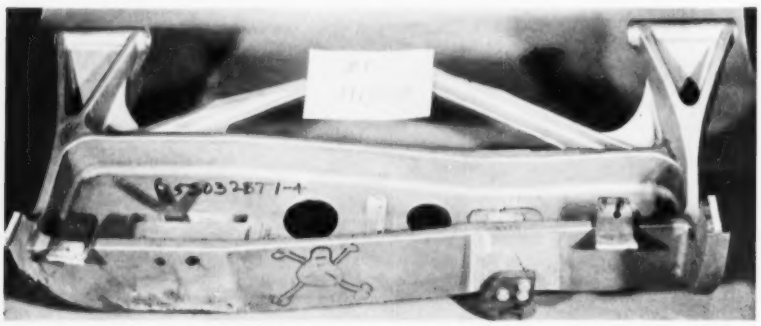


Fig. 4 — A cast jato rack after failure from load static test.

3) Straightening or force fitting of 220 castings caused a few cases of stress-corrosion cracking that the Bureau of Aeronautics became aware of. Straightening of the casting caused localized precipitation along planes of slip, and these localized areas of highly anodic material led to early failure.

It is important to be sure that any 220 sand castings designed for possible use in a marine atmosphere be of a size and complexity which will allow as rapid a quench as possible. Susceptibility to stress-corrosion cracking of 220 sand castings is decreased considerably as the rate of quench is increased.

In 1950 the author's company received a contract to prototype and produce a fighter aircraft which would have the ability to sweep its wings in flight. The fittings which were designed to allow the loads to be properly transferred to a central point required very large 2014 forgings.

Figure 6 is shown to give an idea of the large volume of metal which had to be used to produce a fitting of approx. 225 lb. Castings were originally considered, but at that time unreliability, low guaranteed mechanical properties and space considerations were deterrents to the use of a casting.

If the casting allowables which are available today were available in 1950, the part shown in Fig. 6 might have been a casting. A 2014 hand forging was selected at that time because of the superior mechanical properties.

Hand Forged — 2014		
Longitudinal	60 ksi Ult.	48 ksi yield, 5% elong.
Long trans. . .	57 ksi	48 ksi yield, 2% elong.
Short trans. . .	54 ksi	48 ksi yield, 1% elong.

Then hand forging was completely machined into a fitting weighing approx. 225 lb. To make this part from bits and pieces, 39 large individual parts would have had to be used. The cost of the material in 1950 was: $1.75 per lb, or $6,125.00 for the billet. Since only a small portion of the metal remained, approx. $5,700.00 worth of chips were generated per fitting exclusive of the expensive machining costs.

Of course the author's company could not continually make these parts from hand forgings, so a die was cut (costing $62,000), and die forgings were made which still needed 100 per cent machining (Fig. 7).

Due to low short transverse mechanical properties it was necessary to put a good margin on any attachments which loaded this part in the short transverse direction. This point is brought up because many engineers feel that castings are the only type parts which contain defects. As we know here this is not true.

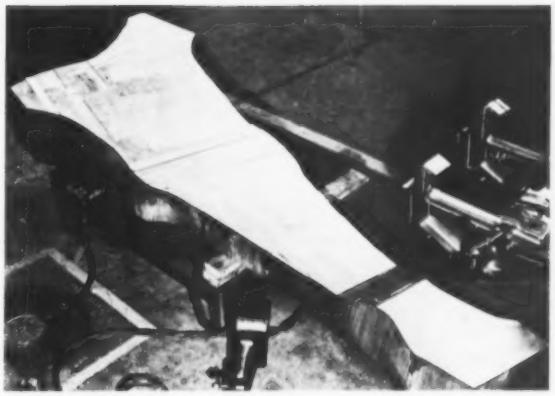


Fig. 6 — Rough cut forging.

A high percentage of wrought products used at the author's company are inspected by ultrasonics. In order to acquaint those not familiar with the reflectoscope, Fig. 8 will help to understand this valuable inspection tool.

The reflectoscope is used by the author's company to inspect steel and aluminum products. For contact testing, a smooth surface is machined on one side of a large billet so that the short transverse grain direction is parallel to this surface. A light machine oil is then applied to the surface to provide intimate contact between it and the quartz searching crystal. The average crystal size is 1 sq in., and has applied to it a frequency of 5 megacycles. A short, high frequency electrical pulse is transformed by this crystal into mechanical vibrations which are transmitted into the billet being tested.

Mechanical echoes come back through the billet and are converted again to electrical pulses, which are then amplified and applied to a cathode ray tube. A pattern is formed on the face of the tube, and any defect which interrupts the echo appears as a blip. The bigger the defect the higher the height. Both contact and immersion sonic testing are used.

The author's company has spent a large sum of money developing a proprietary set of curves which show the reduction in strength due to the defects found by the reflectoscope. Several aluminum produc-

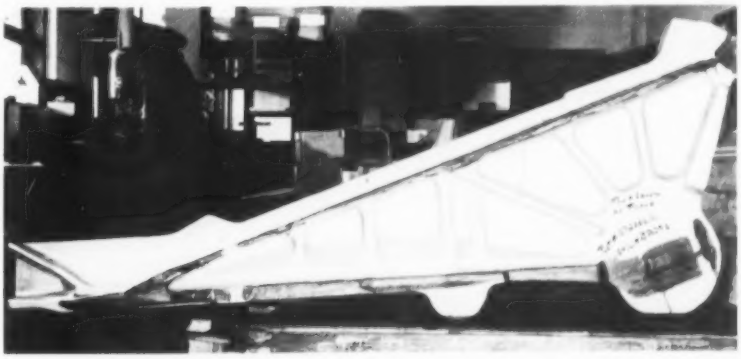


Fig. 7 — A die forging. These parts still needed 100 per cent machining.

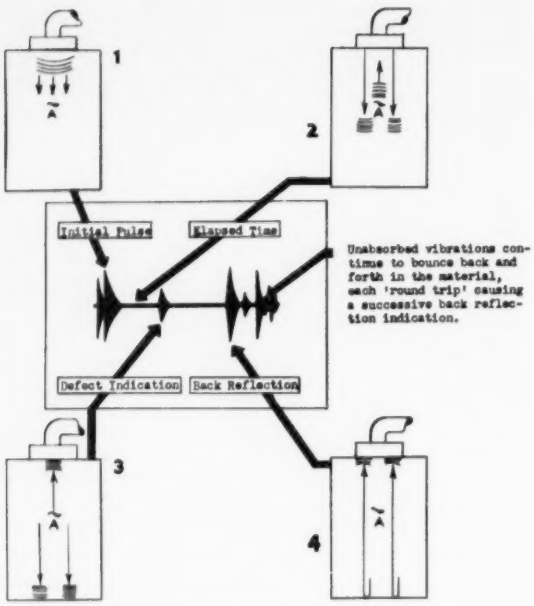


Fig. 8 — Principles of reflectoscope operation for ultrasonic testing of wrought parts. 1) Electrical pulses are transformed into ultrasonic vibrations and transmitted to material. The portion of the electrical pulse delivered to the cathode ray tube causes an initial pulse indication. 2) A portion of the vibrations traveling through the material strikes the defect (A). The sweep travel indicates the time elapsed since the vibrations left the searching unit. 3) The portion of the vibrations which struck the defect (A) bounces back to the searching unit and is transformed back into electrical pulses causing appearance of a vertical indication on screen. 4) The remainder of the vibrations travel to the bottom of the part and are reflected back to the searching unit. The indication of their return is known as the first back reflection indication.

ing companies feel that the company is too conservative in the analysis of ultrasonically located defects vs. strength reduction, but experience has taught the company to be so. Serious trouble in 1948 with die forged 2014-T6 landing gear outer cylinders required the limiting of the maximum operating stress at the parting line to 20 ksi, although it should be mentioned that the last few years have brought about tremendous quality improvements in wrought aluminum products.

A high strength aluminum casting was considered for the pylon stores fittings for the airplane. This fitting serves the purpose of holding a weapon or a 150 gallon fuel tank on the bottom side of the wing. A 2014-T6 forging was first considered and found to be rather heavy and bulky, so a hypothetical casting was next analyzed. The casting actually proved to be lighter due to the cored construction. As the company was preparing to proceed further with an aluminum 356-T6 casting, the analysis indicated two areas on the casting which would be marginal, so an aluminum casting had to be discarded for this part. A flash welding method of fabrication was next considered but the tooling costs were prohibitive. The part finally ended up as a 4330 steel casting which is working out well in production (Fig. 9).

In this case aluminum casting alloys did not have sufficient strength. There are many parts on an airplane which would be considered as castings if more strength could be obtained in light metal castings. These include the many bulkhead fittings which weigh 30-40 lb, which are currently being made from either 7075-T6 or 2014-T6 wrought alloys.

The ultimate possibility in the potential use of castings would be in areas such as the under side of wings. These parts are presently being made from thick plate material and machined all over. As an example, here are a few statistics on the manufacturing details of the lower wing skins of one airplane. For this airplane 1⅝-in. stretched 7075-T6 aluminum plate measuring approximately 16 ft x 4 ft and weighing approx. 1500 lb is used. The plate is ultrasonically tested, then milled into an integrally stiffened part weighing approx. 200 lb. The machining takes about 30 hr on a large skin miller.

The 30 hr would not be so bad, but the availability of these machines is limited. If, some day it would be possible to make parts like these from castings, huge savings in machinery, manpower and dollars would result. As a point of interest concerning these types of parts, a large Army transport aircraft made by milling plate generated 15 tons of scrap (floors and skins).

In conclusion, it is felt that castings, if developed to the point where they can meet strength requirements of 60 ksi ultimate strength, 50 ksi yield strength and 5 per cent elongation, will find wide use in future aircraft.

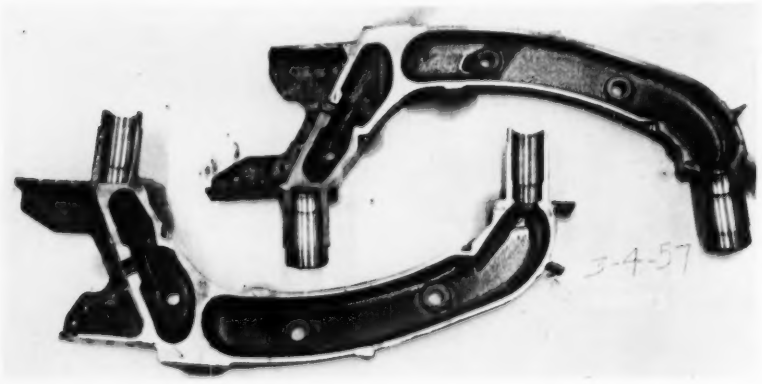


Fig. 9 — Sectioned pylon casting.

DESIGN ENGINEERING AS RELATED TO MAGNESIUM CASTINGS

By George H. Found

ABSTRACT

This is a conceptual treatment of how to go about designing in magnesium castings. It treats the subjects of structural and casting design separately, and then attempts objectively to relate the two. The results when applied to magnesium can be a rather unique situation, where the best features from both structural and casting standpoints become indistinguishable.

The optimum circumstance is one where the service performance can be described and related to available mechanical property data. The resulting structures can then be evolved into configurations which quite coincidentally are preferred for best foundry practices.

INTRODUCTION

The purpose of this paper is to aid in the appraisal and designing of magnesium castings for the aircraft and the broadening missile and electronics fields.

Several methods might be used to treat this subject.

a) A simple statistical comparison of the abundant mechanical property data of the various magnesium and competitive casting materials.

b) A more involved statistical comparison of these data. In this approach the sensitivity of these data to foundry and other quality variables would be considered together with putting emphasis on those data most directly related to the type of design loads that are most critical, whether they are sustained (or creep) loads, dynamic (or fatigue) loads, impact loads, elevated temperatures, corrosive environments, etc.

c) A treatment of certain concepts involved in designing where the characteristic features of magnesium, particularly its physical properties, may be employed to advantage, thus complementing mechanical property comparisons.

Data describing (a) and (b) are readily obtainable from several sources, including publications of The Dow Chemical Co., and will not be considered here.[1,2,3] This paper will contemplate, as in (c), the design opportunities and design practices suggested by the physical properties of magnesium, particularly its density and amenability to highly simplified design.

Since one of the objects of this paper is to recommend best design practices for magnesium, it is helpful to reflect upon what is meant by "good design."

WHAT IS "GOOD DESIGN"?

Good design implies a structure which gives best service performance with least weight, while still retaining a capability for being cast at good production rates.

The use of both good service performance and castability as factors in good design may seem routine. In actual practice, however, it frequently is not. This unfortunate situation arises out of the usual separation of the engineers responsible for the function of the part from those charged with its fabrication. A further influence in this direction is the fact that in many materials there is but limited opportunity for matching best design for serviceability with best design for castability.

WHAT CONSTITUTES GOOD "STRUCTURAL" DESIGN AND HOW DO YOU APPROACH IT?

Good structural design is often described in terms which convey the following:

a) The material is chosen whose mechanical properties are adequate to sustain the critical loads taking into account their mode, direction and rate of application under the expected environmental conditions. It is desirable also that the material be selected to match the design with respect to the presence of stress raisers or notches. In this regard, a structure with unavoidable ribs, unavoidably sharp radii and abrupt changes of section should be matched with a material or alloy or heat treatment that gives the plasticity to permit as much load redistribution as possible.

b) The design is one which comes as close as possible to allowing all portions of the structure equally to share in supporting or distributing load.

c) The structure has no excess metal, but was designed from the low side toward the condition of adequacy, including prescribed safety factors.

Of great assistance to designers in the light metals is the relatively extensive supply of mechanical property data available. The accumulation of such data during and since World War II for both magnesium and aluminum alloys permits certain approaches to designing in the light metals which are not possible for the other structural materials.

G. H. FOUND is senior staff member, Eng. Div., Arthur D. Little, Inc., Cambridge, Mass. This paper was prepared when the author was Gen. Mgr., Saginaw Bay Industries, Inc., Bay City, Mich.

When light alloy castings are to be used, the designer frequently may start with a completely new design, as is usually the case for aircraft and missile components; or start on the basis of a previous design in another metal for which the light alloy casting is to be substituted. The stepwise procedure followed for either approach is outlined in the Table.

NEW DESIGN

These procedures preclude the use of ordinary cut-and-try methods since such methods offer little chance for arriving in a short time at a design of as high structural efficiency as by the procedure outlined in Table and described hereafter. Cut-and-try methods are being modified as the demands for higher structural efficiency become more intense, and as metal strength data for use in predicting service and the facilities for experimental and theoretical stress and thermal analysis are employed.[4,5,6]

Structural uses for which the designer must develop a new design frequently involve complex design requirements where loading and other factors defy predictability. In these cases, a prototype casting is made based on matching theoretical loading requirements against the known safe static, fatigue, impact and creep strength property values given for the metal.

At this point, two problems must be considered. The first is the method for accurately predicting service loading requirements. The accuracy of theoretical design analysis for predicting service conditions in castings where complicated loading is involved is inadequate. Such calculations usually must be predicted on simple static loading and do not properly consider complex dynamic loading, fatigue and impact problems and stress concentrations that may be critical regardless of the thickness of wall sections, or other design details in the immediate proximity of the stress raisers. Theoretical calculations, consequently, serve only as a starting point in the design project.

The second problem involves predicting serviceability from the available mechanical property data. The only data that can be used are those which can be interpreted, to the proper degree, in terms of the foundry and other practical variables that are likely to be present.

These variables include the effects of porosity, grain size, perfection of heat treatment, surface smoothness (as cast surfaces vs. machined surfaces) and stress concentration. If data are available and experience has been obtained to demonstrate how the data can be used directly for design purposes, the first design can then be established.

TABLE – BASIC STEPS IN DEVELOPING A NEW OR SUBSTITUTE DESIGN

I. Developing A New Design—Sequence of Steps for Establishing Final Design	
a. Theoretical Determination Of Loads	
b. Matching Above Loads Against Known Metal Strength Information To Establish Initial Design	
c. Creation Of Prototype Casting	
d. Static And Dynamic Experimental Stress Analysis During Service Or Simulated Service Loading	
e. Matching Results Of Stress Analysis Against Known Metal Strength Information To Establish Final Design	
f. Creation Of Casting To Final Design	
g. Final Proof Testing	
II. Developing A Substitution Design—Sequence of Steps for Establishing Final Design	
a. Assumption That Design In Former Metal Is Adequate – Or Revisions To Allow For Structural Inadequacies Or Changes In Fabrication Procedure	
b. Matching Sections Of Previous Metal With Proposed Light Metal Designs, Taking Into Account Known Metal Strength Information For *Both* Previous Metal and Proposed Light Metal To Establish Initial Design.	
c. Same As c Above	These steps may eventually be excluded when experience with the procedure in (a) and (b) is perfected and when strength data in (b) become adequate for forecasting serviceability for all structural metals.
d. Same As d Above	
e. Same As e Above	
f. Same As f Above	
g. Same As g Above	

SUBSTITUTION DESIGN

It is often advisable, when changing materials, to develop a new design from scratch, thereby permitting freedom for attacking the problem as a whole. In some cases, however, when materials are being changed to magnesium or aluminum, it is imperative that the starting point for designing be the design in the metal previously employed. If it is assumed that the period of service of the part in the previous metal resulted in the evolution of a successful design in the previous material, the problem is then simplified for the designer. The usefulness of complete strength data again becomes apparent, however.

In this case, the designer may substitute magnesium or aluminum, taking into consideration the respective strength properties of the previous and the proposed new metal. Essential for this procedure is complete strength information for the previously used material. This, however, is frequently not as complete as the information available describing the light metals, and, therefore, poses another problem in simple substitution techniques.

If it is known that the part to be converted to light metal alloys is not adequately designed, alterations can be planned at this time based on the previous service information on the part. Frequently certain features of the previous design were necessary to enable given fabrication methods to be employed. Such would be the case where pressed or formed steel parts are involved.

When a casting is designed to replace a formed and assembled part, sections should be changed to accommodate the casting process. Certain section thicknesses and design details were incorporated in the previous design only to facilitate forming and should be identified and altered to favor the casting process and structural efficiency requirements.

After the initial design is established, based on theoretical load calculations or material substitution criteria involving accurate material strength data, an initial casting is made. The efficiency of this first design is then evaluated by experimental stress checks. Metal strength data, if available and sufficiently extensive, are again used for comparison with stresses measured in the experimental stress analysis.

On the basis of this comparison, superfluous metal can be removed where working stresses are judged

to be far below the critical strength values for the metal, or metal added where stresses are above or too close to the critical strength values. A new, and perhaps final, casting design is then made.

WHAT CONSTITUTES GOOD "CASTING" DESIGN AND HOW DO YOU APPROACH IT?

Good casting design is that which gives the foundryman the best chance to achieve uniformly high properties throughout the structure of the casting, while still maintaining the rates of productivity that his type of operation requires.

A study of factors regarding wall configurations is fundamental to good casting design. For castability reasons, the minimum wall thickness desired in magnesium castings should not be under $\frac{3}{16}$-in. For small areas, however, $\frac{5}{32}$-in. or even $\frac{1}{8}$-in. can be maintained. Standard casting design, as it has developed over the years with the heavier metals, has tended toward the use of as thin sections as castability will allow, rigidized and strengthened by the addition of ribbing systems.

So long as the fluidity requirements are satisfied, thin sections do yield mechanical properties superior to thick sections or variable sections.[7] Such thin structures, however, do show lower property values at the intersections of ribs and in sections heavied-up for added strength. These thick-and-thin features impose the need for provisions to feed and otherwise specially to favor the heavier sections, in order to prevent and to control porosity and the lower properties that develop in adjoining areas.

Extensive studies started during World War II and which have been continued to date measure the effect on mechanical properties of foundry-induced variables of this type. The mechanical properties of the uniform thin areas approach, more closely than do variable sections, the properties of cast test bars, and, thus, show better promise to the design engineer by giving average strength properties higher than the specified 75 per cent of test bar minimums.[8] Indeed, the disparity in mechanical properties that exists between test bars and coupons cut from castings demonstrates how much improvement can result if more uniform cast structures as in test bars could be accomplished in castings.

The best structure from a casting standpoint thus can be visualized to be one that is not so thin in the overall wall areas as to require ribbing and rigidizing, but rather one that is somewhat thicker and uniform, and not requiring such irregularities as ribbing systems. Recent studies show that such uniform structures in magnesium yield better properties than the thick-and-thin type configurations which result from thin webs and thick intersections between ribs and highly filleted wall areas.[9]

WHERE DOES MAGNESIUM FIT IN?

Mechanical property data reveal to design engineers why magnesium is of interest. Magnesium may be used in many applications on an equal volume basis, with a full weight saving in proportion to relative densities.

If a small amount of magnesium is added to the general wall thickness of the previous heavy metal design, the ribbing can be eliminated. The magnesium structure resulting is only a few per cent heavier than the ultimate weight saving offered by magnesium on equal volume basis substitutions. Thus, the rigidity and strength of the increased thickness, which increase by the cube and square, respectively, become quite adequate for most applications without the complications of rigidizing ribs and other complicated stress raisers. In structural analysis studies, many designers have come to the conclusion that ribs do not materially strengthen castings, proof of which is provided in both practical and theoretical treatments. Instead of strengthening the structure, such ribbing systems provide stress concentration zones, poor quality zones and crack propagation centers, especially in dynamically loaded parts, that more than offset the reasons for introducing them in the first place. The literature has become quite well documented with experimental stress analysis and theoretical proofs of the fact.[9,10]

Most magnesium sand castings are sufficiently massive after the above treatment that the lower modulus of elasticity of magnesium becomes a much reduced problem. The avoidance of stress concentrations by the adding of wall thickness rather than ribs is in accordance with the recommended practices for generous filleting. The use of a large number of fasteners modestly loaded rather than a few fasteners heavily loaded, the use of longer studs or through bolts, the avoidance of sharp corners particularly around bosses and the use of alloys of magnesium in the heat treatments that provide maximum toughness rather than only highest strength and maximum hardness are in accordance with this practice.

The lower modulus of elasticity of magnesium alloys may contribute to better serviceability in some cases since it effects an improved distribution of load to the principal load carrying members, thus contributing to the efficient use of metal in the structure.

One of magnesium's most favorable features is its high dimensional stability at elevated temperatures providing recommended heat treatments are applied.

The coefficient of thermal expansion of magnesium is somewhat higher than for the heavier structural metals. This should be taken into account to avoid the development of high stresses which would lead to creep and distortion.

SPECIFIC DESIGN APPLICATIONS FOR MAGNESIUM CASTINGS

An original aluminum crankcase for a 12 cylinder aircraft engine was of conventional design with heavily ribbed sections, as shown by the section in the upper left view of Fig. 1. The part did not pass qualifying tests and was overweight. The part was changed to magnesium. The ribs were removed from the sidewalls and from the bearing diaphragms, as shown in the section in the lower right view of this Fig. 1.

Stress concentrations were thus reduced and wall thicknesses were increased slightly, so that the section

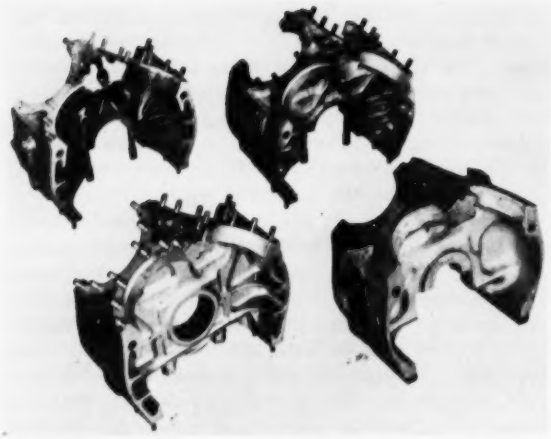


Fig. 1 — Evolution of a clean design in a crankcase; bearing support section is shown. Initial design is upper left. Sequence follows to upper right, lower left to final at lower right. Ref. (9).

modulus at highly stressed sections was increased and the lower modulus of elasticity was offset. The resulting magnesium crankcase did pass the qualifying tests with more than twice the endurance of the initial ribbed aluminum structure, but with a 25 per cent weight saving.

The procedure above is shown as it progressed through the stages of design simplification; upper left to upper right, to lower left hand to final structure lower right hand. Note the absence of ribs in the clean final design.

An aircraft camshaft housing, Fig. 2, was converted from aluminum to magnesium and the design simplified in similar fashion. The old version in various areas is at the left. The changed structure is at the right of the figure. The removal of ribs and the slight addition of wall thickness reduced stress levels 55 per cent with no increase in weight or flexibility.

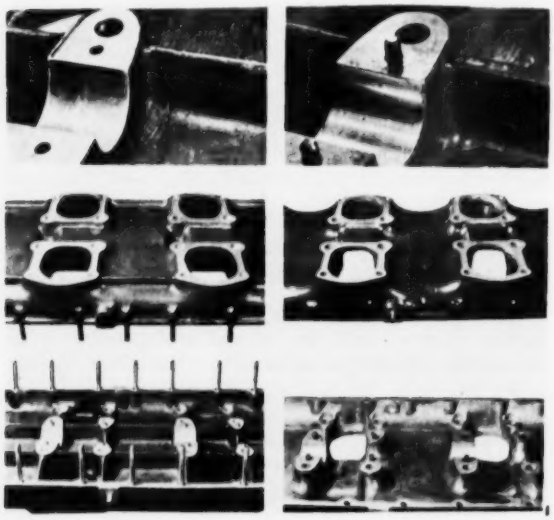


Fig. 2 — Same as Fig. 1 for camshaft housing. Design features before simplification are at left, and after is at right. Ref. (9).

Similar simplifications in aircraft wheel design have taken place. The intricate, highly ribbed wheel structures, Fig. 3, are giving way to the simpler design, Fig. 4, with reduction in cost and increases in service life under critical fatigue loading. These structures have become sufficiently clean that some are now being either permanent mold cast or forged, rather than sand cast.

A final series of views show two other areas of magnesium casting application of interest to aircraft and missile designers. Figures 5 and 6 show a sand cast magnesium missile wing, an application warranted by the development of strength and rigidity in bending by slight increases in wall thickness, but without weight penalty when compared to the heavier structural materials.

Figures 7, 8, 9 and 10 show various die cast and sand cast magnesium electronic chassis components. These are good magnesium applications in today's

Fig. 3 — Aircraft wheel of previous ribbed design.

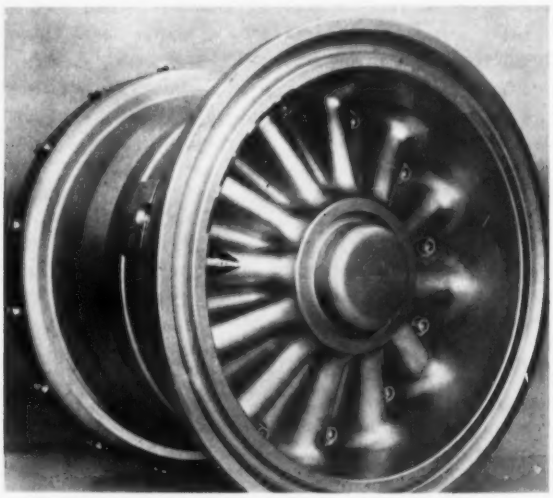


Fig. 4 — Aircraft wheel of simplified ribless design.

highly instrumented missile and aircraft applications, because of the high degree of rigidity and structural stability that can be developed without prohibitive weight penalties.

CONCLUSIONS

A critical view of the structural design and casting design possibilities for magnesium reveals what can be termed a break-through in design opportunities. Alloys of cast magnesium are being designed in configurations to approach not only the foundryman's ideal in design, but the designer's ideal as well.

The designer's ideal, as already described, is one where stress concentrating features can be avoided without the penalties of excessive weight from built-up wall thicknesses, and where simple functional design without re-entrant sections in complicated load distributing patterns are eliminated.

For the foundryman, the ideal design is one of uniform, relatively thin sections where feeding prob-

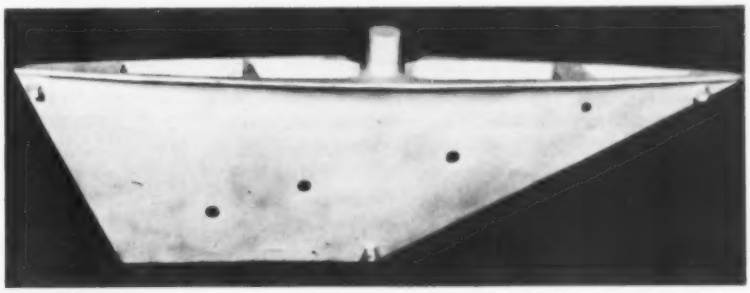


Fig. 5 — Sand cast magnesium missile wing before finishing.

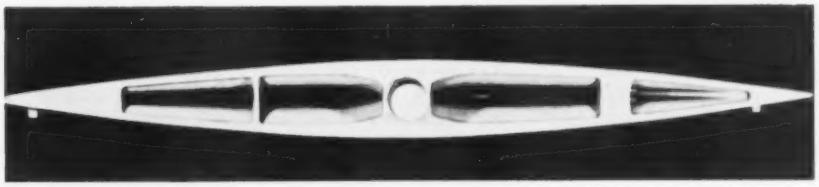
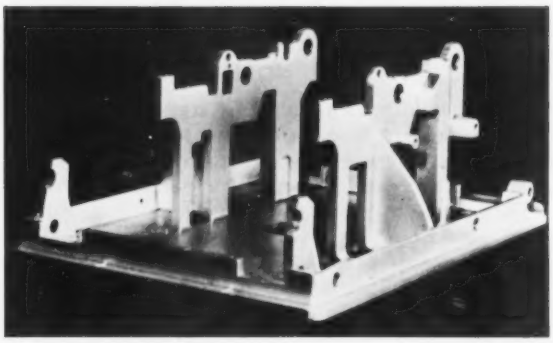
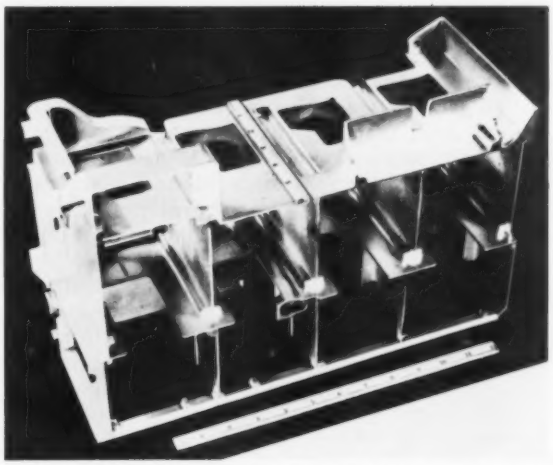
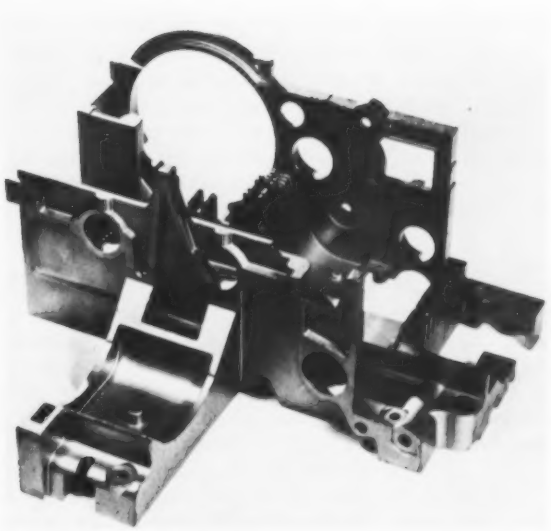


Fig. 6 — Same as Fig. 5. End view.







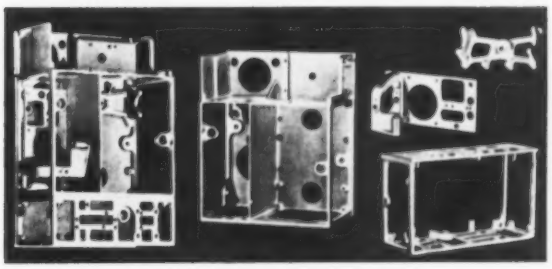


Fig. 7, 8, 9, 10 — Various cast magnesium chassis components for electronics units.

lems are simple, walls are without abrupt change in thickness or directionality and metal flow and solidification can be controlled without the complications of elaborate feeding and risering systems.

The so-called simple, clean "forging-like" design is the result of these procedures.

ACKNOWLEDGMENT

All figures and tabular matter of this paper are courtesy of The Dow Chemical Co., Midland, Mich.

REFERENCES

1. John C. McDonald, "Tensile, Creep and Fatigue Properties at Elevated Temperatures of Some Magnesium-Base Alloys," A.S.T.M., *vol. 48*, (1948).
2. George H. Found, "The Notch Sensitivity in Fatigue Loading Of Some Magnesium-Base And Aluminum-Base Alloys," A.S.T.M., *vol. 46*, (1946).
3. "Room and Elevated Temperature Properties Of Magnesium Casting Alloys," Bulletin No. 141-176, The Dow Chemical Co., Midland, Mich.
4. George H. Found, "Fatigue Characteristics of Magnesium Castings" A.S.T.M., (1946).
5. George H. Found, "The Relative Significance of Design and Metallurgical Factors To The Serviceability of Magnesium Castings," AFS TRANSACTIONS, *vol. 54*, p. 93, (1946).
6. George H. Found, "Efficient Magnesium Castings – Their Design and Production," *Metal Progress*, p. 833, Dec., 1954.
7. M. C. Flemmings, R. W. Strachan, E. J. Poirier, H. F. Taylor, "Performance of Chills on High Strength Magnesium Alloy Sand Castings of Various Section Thickness," AFS TRANSACTIONS, *vol. 66*, p. 336, 1958.
8. Military Specification QQ-M-56.
9. W. T. Bean Jr., "Simplification of Light Metal Casting Design and Its Effect Upon Serviceability," AFS TRANSACTIONS, *vol. 55*, p. 430, (1947).
10. Anonymous, "Minimum Ribbing For Maximum Strength," *Die Casting*, Feb., 1949.

FACTORS INFLUENCING SOUNDNESS OF GRAY IRON CASTINGS

a review of some recent British work

By I. C. H. Hughes, K. E. L. Nicholas, A. G. Fuller, and T. J. Szajda

ABSTRACT

The constitution of nearly all gray irons leads to both contraction and expansion stages during their solidification, and soundness is to a large extent dependent upon the detailed way in which these volume changes act. In many castings, general expansion of the casting during solidification is associated with the formation of shrinkage defects. Casting expansion is promoted by mold cavity volume changes, which are more pronounced in softer molds and are dependent upon pouring temperature and molding sand type and properties.

Major composition of the iron also affects casting expansion and soundness by influencing the eutectic graphite amount. Phosphorus leads to soundness problems because of the presence of a low melting point phase. An important finding is that increasing the degree of nucleation of the graphite eutectic leads to unsoundness. This is a common foundry variable which can be measured, and is amenable to some control.

NATURE OF GRAY IRON SHRINKAGE

Shrinkage defects in light and medium sectioned gray iron castings are comparatively rare, unless the composition is strongly hypoeutectic or contains more than about 0.2 per cent phosphorus. Many British castings, particularly those of light section, contain over 1 per cent phosphorus, and considerable technical skill is necessary to make sound the wide range of castings produced from such irons. Early research work on soundness was, not unnaturally, largely confined to investigations of major compositional variables, in particular carbon, silicon and phosphorus.[1]

Such investigations clearly demonstrated the important influence of composition on soundness, but were limited in their practical application. This is because it was apparent that within a given foundry melting an iron of fairly constant composition under repetitive conditions, there were other undetermined variables operating. These were causing greater variations in the incidence of shrinkage defects than could be explained by the most careful analysis of the effect of the minor changes in composition.

Research over the past decade has led to the belief that apart from liquid shrinkage prior to solidification, the actual solidification of the commonly used gray irons does not involve a net shrinkage, except in irons of hypoeutectic composition or in noneutectic high phosphorus irons. However, the solidification sequences of gray irons involve two or three stages in which either shrinkage or expansion are occurring. It is the way in which the associated volume changes act which leads to the occurrence of shrinkage defects.

These volume changes result either in the reduction of shrinkage cavities, or in an overall expansion of the casting creating further unsoundness. This fact is highlighted by the spectacular increase in the incidence of unsoundness in nodular graphite irons, compared with flake graphite irons of the same major composition, in which the same quantities of graphite and austenite form during solidification.

The precipitation of graphite is accompanied by a relatively large increase in volume, which has been shown to give rise to proportional expansion of the casting during this stage of solidification.[2]

The main variables governing the formation and magnitude of shrinkage defects are mold rigidity, pouring temperature, constitution and the degree of nucleation of the austenite-graphite eutectic. These variables have been extensively investigated at the BCIRA, and some of the more important results are reviewed in this paper.

HOW GRAY CAST IRONS SOLIDIFY

In order to understand the fundamental types of shrinkage unsoundness characteristic of the main kinds of gray irons, a knowledge of their solidification sequences is necessary. This subject has received considerable attention.[3,4,5] The solidification sequence of an iron controls the distribution of solid and liquid eutectic throughout the casting, this in turn controlling the nature and distribution of shrinkage defects. The magnitude, time and uniformity of the casting dilation relative to the net solidification volume changes govern the severity of the shrinkage defect.

In hypoeutectic irons the initial process is the precipitation of austenite dendrites, a stage of solidification involving a shrinkage. Because of the presence of eutectic liquid dispersed throughout the casting, it is unlikely that any internal cavity formation can occur at this stage of solidification. Shrinkage is therefore accommodated either by top surface or hot spot piping or, alternatively, by the supply of feed metal through the gates or from an external feeder.

I. C. H. HUGHES, K. E. L. NICHOLAS, A. G. FULLER and T. J. SZAJDA staff members, The British Cast Iron Research Assoc., Alvechurch, Birmingham, England.

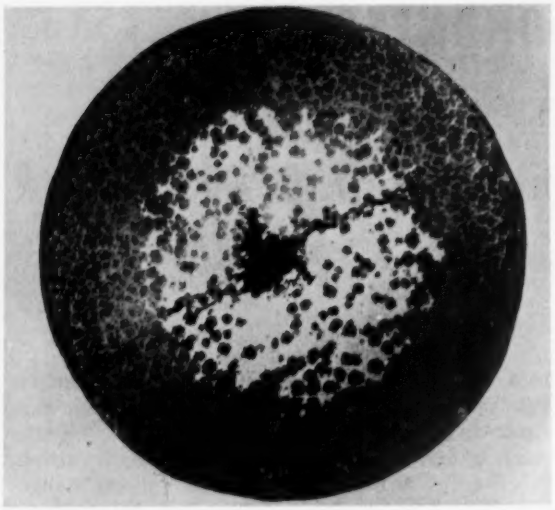


Fig. 1 — Macrostructure of quenched gray iron bar, showing region of solidified eutectic at edge of casting and simultaneous dispersed solidification of eutectic cells throughout the interior.

Subsequently the binary graphite/austenite eutectic solidifies with an expansion which will tend to force the last remnants of liquid out of the top of the casting to appear as plugs in previously formed pipes, or out of hot spots as exudation defects. Alternatively, a general increase in the size of the casting may occur.

The graphite/austenite eutectic solidifies throughout the casting in discreet cells. Within each cell the graphite is interconnected, as has been demonstrated by deep etching techniques. The cells are roughly spherical, and solidification proceeds fastest at the edge of the casting to form a continuously thickening shell of solid eutectic, although at the same time cells are growing throughout the interior of the casting. This type of solidification, which does not represent true directionality, is illustrated in Fig. 1 (from the work of Gittus[6]). Figure 1 shows the macrostructure of a gray iron casting quenched during eutectic solidification.

The casting skin and the semi-solid casting interior are sufficiently plastic to permit deformation of the casting due to either mold wall movements or expansion accompanying the precipitation of graphite.

Figure 2 represents schematically an intermediate stage in the solidification of a low phosphorus hypoeutectic flake graphite iron, and is based upon the results of quenching experiments and thermal analysis. In irons of this type it is rare to find internal porosity, but piping may occur at hot spots and junctions between sections of differing thickness.

Solidification sequences of hypereutectic irons differ from those of hypoeutectic irons only in the nature of the primary phase.[5] Precipitation of primary graphite occurs over a range of temperatures, and is accompanied by liquid shrinkage. This liquid shrinkage almost certainly more than compensates for the expansion accompanying the primary graphite precipitation.

Increasing the phosphorus content of a flake graphite iron above 0.2 per cent considerably changes the shrinkage characteristics of the iron, and may lead to the formation of either interdentritic porosity, or alternatively localized shrinkage cavities. An explanation for this is given by a study of the solidification sequence of a 1.1 per cent phosphorus flake graphite iron.

In irons of this type flake graphite, eutectic solidification is substantially completed while the eutectic cells are still surrounded by a network of phosphide eutectic liquid, as shown in Fig. 3. This liquid is thought to form a continuous network even at quite low phosphorus contents, although only isolated particles appear in sections under the microscope. By deeply etching nodular irons of various phosphorus contents, it was possible to remove the matrix completely and to shake out the graphite nodules, revealing the phosphide network which surrounded the eutectic cells. A representation of the resulting structure, in a 0.4 per cent phosphorus iron, as seen under a binocular microscope, is shown in Fig. 4.

The melting point of the phosphide eutectic is about 950 C (1742 F), some 200 C (392 F) lower than that of the graphite eutectic. Hence, a stage of solidification is reached when the casting is solid except for a network of phosphorus-rich liquid.[4] This liquid remains throughout the casting in spite of quite steep temperature gradients which may exist in the latter stages of solidification in some castings. Finally, the phosphide eutectic solidifies progressively throughout the casting.

The solidification sequence of nodular iron differs from that of flake graphite iron mainly in two respects. The solidification of the austenite/graphite eutectic is more dispersed (Fig. 5), the last liquid being widely dispersed in fine interconnected channels throughout the casting. Unlike the last liquid in phosphoric irons, it consists of ordinary liquid graph-

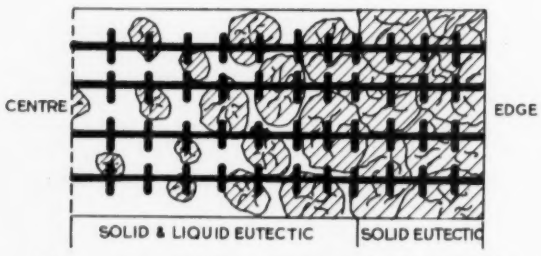


Fig. 2 — Low phosphorus hypoeutectic flake graphite iron, intermediate stage of solidification.

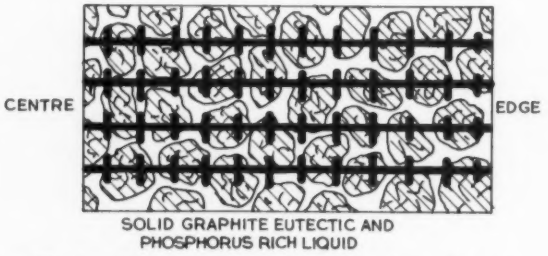


Fig. 3 — Hypoeutectic flake graphite iron (1.1 per cent phosphorus), late stage of solidification.

ite eutectic at a temperature close to its solidification point. Consequently, while liquid remains it can flow and be replaced with ordinary feed metal of near-eutectic composition.

In addition, the eutectic cells in a nodular graphite iron are smaller and far more numerous than in a flake graphite iron, and contain only one graphite particle in comparison with the numerous interconnected flakes within each eutectic cell of a flake graphite iron.

HOW SHRINKAGE DEFECTS OCCUR

Castings liable to contain unsoundness are sounder when poured in rigid molds than similar castings of the same composition and pouring temperature cast in green sand molds.[7] This appears to be true for all types of gray iron, irrespective of the probability that most common compositions solidify with a net expansion. Furthermore, although low phosphorus flake graphite irons are generally sound, nodular graphite irons of the same major composition frequently require feeding or contain appreciable internal porosity.

An explanation of this phenomenon is offered by the work of Gittus,[8] who showed that the expansion tendency of the casting during solidification of the eutectic is much greater in nodular irons than in flake graphite irons. The comparison is shown in Fig. 6.

Clearly an interpretation of the behavior of these two irons suggests that the expansion accompanying eutectic solidification can either cause self-feeding of the casting with exudation of liquid eutectic through a previously formed pipe defect, or alternatively a general expansion of the casting. These two alternatives are represented diagrammatically in Fig. 7. The mechanism (c) is suggested as being the most probable in low phosphorus flake graphite irons, although even in irons of this type some expansion occurs unless rigid molds are employed.

The mechanism (d) represents the behavior of nodular graphite irons in green sand molds, and will also explain the formation of internal porosity in this type of iron. This has indicated a method whereby the soundness and yield of nodular graphite irons can be increased, namely, by the use of a rigid mold to restrict casting expansion. Using rigid molds, casting expansion in nodular irons has been eliminated and purging of liquid eutectic observed (Fig. 18) together with a soundness improvement.

In low phosphorus flake graphite irons the expansion due to the solidification of the last liquid is normally sufficient completely to fill the enlarged casting, that is, the casting is self-feeding. However, increasing the phosphorus content is accompanied by a progressive increase in internal porosity. This may be a consequence of the following factors.

1) Additions of phosphorus progressively reduce the proportion of the total eutectic which appears as the binary austentite-graphite constituent. Quenching experiments have shown that in a particular 0.4 per cent phosphorus iron, 95 per cent of the total eutectic is made up of the austentite-graphite phases, whereas in a 1.1 per cent phosphorus iron of the same carbon equivalent, the proportion of the austentite-graphite phases has been decreased to 70 per cent of the total eutectic. This effect of phosphorus is equivalent to decreasing the amount of eutectic graphite.
2) The presence of a network of phosphorus-rich liquid throughout the casting.

Fig. 4 — Sketch of phosphide eutectic network in a 0.4 per cent phosphorus nodular graphite iron.

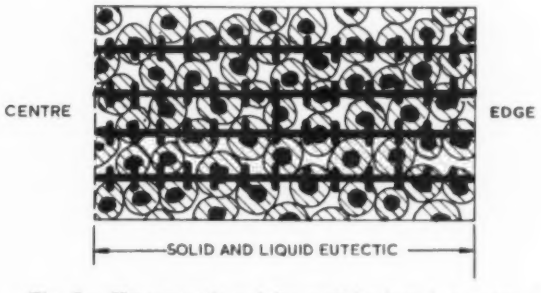


Fig. 5 — Hypoeutectic nodular graphite iron, late stage of solidification.

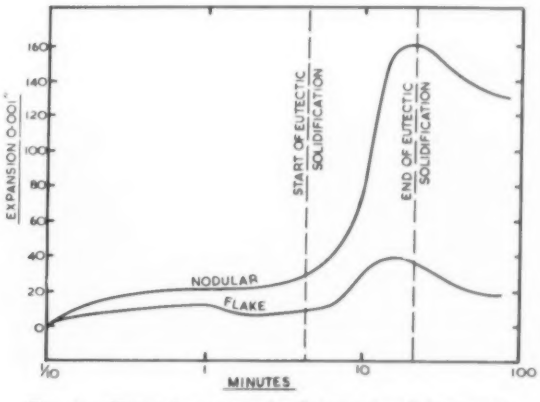


Fig. 6 — Expansion curves for flake and nodular graphite iron castings poured in green sand molds.

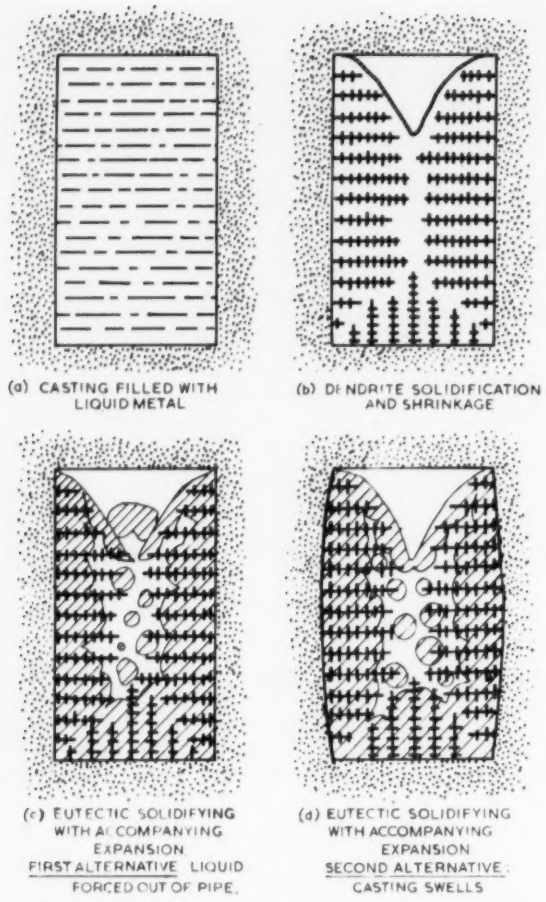

(a) CASTING FILLED WITH LIQUID METAL
(b) DENDRITE SOLIDIFICATION AND SHRINKAGE
(c) EUTECTIC SOLIDIFYING WITH ACCOMPANYING EXPANSION
FIRST ALTERNATIVE LIQUID FORCED OUT OF PIPE.
(d) EUTECTIC SOLIDIFYING WITH ACCOMPANYING EXPANSION
SECOND ALTERNATIVE: CASTING SWELLS

Fig. 7 — Solidification of gray iron castings.

3) Overall expansion of castings during eutectic solidification in softer types of molds may be greater than the expansion due to eutectic graphite. The colder first parts of the casting to solidify therefore draw last eutectic liquid from the hotter parts of the casting. When the last liquid is phosphorus-rich, it will drain from the hot spots by this mechanism to leave a characteristic network of porosity.

During cooling of the casting to the phosphide eutectic temperature, liquid shrinkage occurs. This, together with volume changes accompanying the solidification of the phosphide eutectic, will further promote the internal porosity typical of phosphoric gray irons.

Fig. 8 — Phosphide exudation (sweat) on a light casting.

The fact that the phosphide eutectic liquid remains in a network throughout a casting when solidification is substantially complete is demonstrated by the fact that under certain conditions this liquid may be exuded at numerous positions on the casting skin, forming the familiar phosphide sweat shown in Fig. 8. In spite of the presence of this network, however, normal feeding through these channels is impracticable, since liquid iron from feeders is unlikely to penetrate for any distance to colder regions of the casting which are substantially below the temperature of solidification of the graphite/austenite eutectic.

FEEDING

Detailed studies of a wide range of castings, varying from a few ounces to nearly 150 tons in weight, have indicated that feeding is necessary to compensate for:

1) Liquid shrinkage, the extent of which is governed by the casting temperature and the proportion of which is approximately constant for all common types of gray iron.[9]
2) Mold cavity and casting expansion, which in a wide range of castings has been shown to correspond closely to the quantity of feed metal supplied. This is illustrated by Fig. 19.

The evidence obtained supports the view that the solidification volume changes of normal gray cast irons do not involve an overall contraction and, therefore, make no demands on feed metal. Liquid shrinkage, which occurs prior to solidification, may be calculated, but mold cavity expansion is dependent upon casting design and mold type. Hence, no explicit rule is possible as to the total amount of feed metal necessary.

For any feeder to contain a supply of liquid metal until the remainder of the casting is solid it would have to be unrealistic in size, especially for larger castings. For this reason it is often more expedient and economical to use on large castings small feeders having insulated sleeves which can be frequently refilled with hot metal.

In general, the principles of directional solidification so commonly applied to steels and white irons cannot be properly achieved in gray irons, because of the dispersed nature of eutectic solidification.

In small, thin section gray iron castings, the effect of mold cavity expansion upon soundness is comparatively small and liquid shrinkage is generally compensated for by feeding through the gates; thereafter self-feeding during eutectic solidification should make the need for external feed metal unnecessary. Self-feeding utilizing eutectic graphite expansion is most successful if solidification is uniform.

This may be achieved by design modifications such as eliminating sharp changes in section and re-entrant corners, or by the use of local pads and chills. It is probable that shrink "bobs" fitted to sprays of small castings serve only to provide a reservoir in the gating system from which hot metal enters the mold cavity.

Nodular iron castings may require large feeder heads for two reasons. First, to compensate for the greater mold cavity expansion occurring during eu-

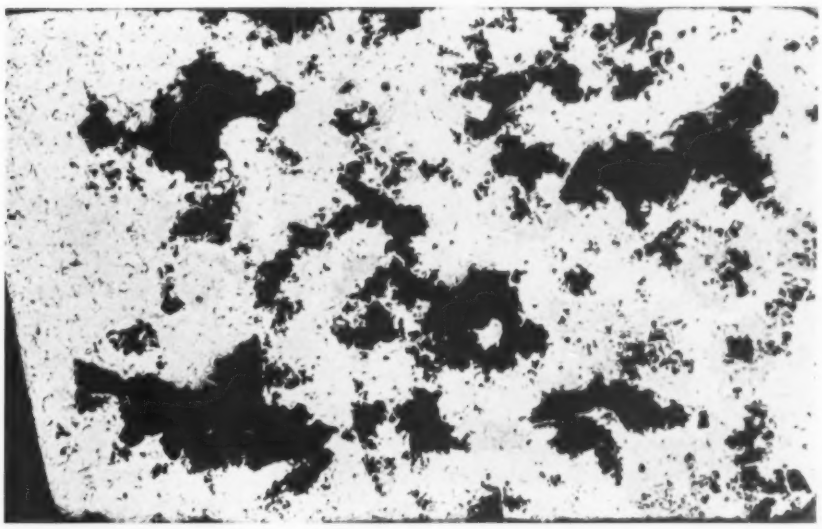


Fig. 9 — Gross porosity in a phosphoric iron casting resulting from mass feeding. 5 ×.

tectic solidification, and second, to promote directional solidification. In an unfed nodular iron casting, the last liquid to solidify, and associated internal porosity arising from casting expansion, is widely dispersed, but unlike phosphoric flake graphite irons normal feeding is practicable.

As has been described previously, shrinkage associated with the solidification of the phosphide eutectic in phosphoric irons is virtually impossible to feed by external means.

If a pronounced hot spot exists in a phosphoric iron casting there may be a flow of phosphide and semi-solid graphite eutectic away from the hot spot. This settling of the semi-solid mass will result in the formation of a gross shrinkage cavity, and is often referred to as mass feeding. This type of defect, illustrated in Fig. 9, can be remedied either by supplying liquid feed metal direct or by removal of the heat center from the casting.

It must always be remembered that a feeder head introduces a hot spot. This is undesirable if the hot spot extends into the casting, so that often it is better to avoid using feeders for flake graphite irons where the necessity for feeding is marginal and to rely upon the self-feeding behavior of the casting.

Green sand, which is the common molding material employed in the light and medium castings industry, suffers from the disadvantage that unless the molds are firmly rammed the castings may exhibit swellings or be oversize. This fact is well known, but it is not so widely recognized that oversized castings tend to be associated with shrinkage defects. The problem is illustrated in Fig. 10, which shows a direct relationship between the incidence of internal porosity and the extent of casting expansion in brake-drum castings.[7]

MOLD CAVITY AND CASTING EXPANSION ARE FUNDAMENTALS

An improvement in casting soundness can be obtained by the use of dry or core sand molds which are more rigid than green sand molds, but such a measure is generally uneconomical except for special or large castings. Common examples of the use of dry sand or loam molds are provided by the manufacture of large engineering castings and ingot molds. Such castings often require substantial post-casting additions of feed metal if they are to be free from shrinkage cavities.

The early feed-metal additions compensate for liquid shrinkage, but it has been clearly demonstrated that large and prolonged additions of feed metal are necessary solely to compensate for expansion of the casting in the apparently rigid mold. Foundry in-

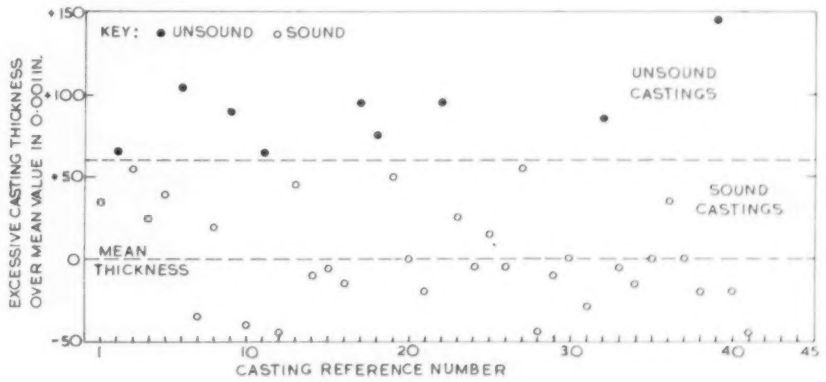


Fig. 10 — Expansion of green sand molded brake drum castings related to internal porosity.

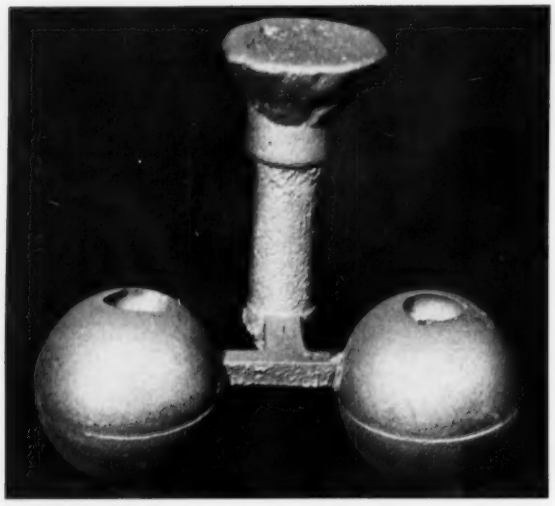


Fig. 11 — Three in. diameter test casting.

vestigations have shown that, for even the largest ingot molds, the increase in casting wall thickness compared with the width of the original mold cavity corresponds closely with the feed metal requirements.

Because of the relatively long freezing range of gray irons, especially those containing phosphorus, the casting is likely to be sufficiently plastic to follow any variation in mold cavity volume during most of the solidification process.[6] Any factor which would alter the volume of the mold cavity during solidification of the casting will be reflected in the ultimate soundness or feed metal requirements of the casting, as is clearly demonstrated by the experimental work described below.

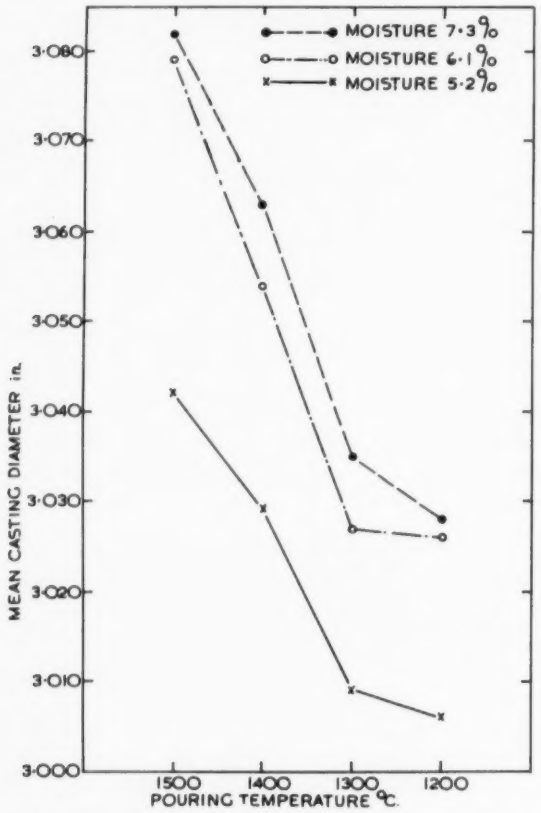


Fig. 12 — Mean casting diameter (in.) vs. pouring temperature.

Investigations to study expansion of unfed gray iron castings have been carried out using 3 in. diameter spheres,[10] as shown in Fig. 11. The variables studied included moisture and coal dust contents of green molding sands. Casting expansion was calculated from direct measurement of the diameter of the sphere in three positions mutually at right angles. The results of these experiments have shown that increasing the moisture content progressively increased the casting expansion (Fig. 12), whereas an addition of 6 per cent superfine coal dust (at constant moisture content) decreased the dilation.

These results are similar to those reported by Gittus,[2] Womochel and Sigerfoos[11] and Wallace and Evans,[12] and clearly indicated that these factors operate by affecting the deformation characteristics of the mold.

Use of the same test piece has shown that the soundness of gray iron castings is significantly improved by the use of materials yielding a more rigid mold. The materials studied included dry sand, CO_2 process and cement sand, and the improvement in soundness arising from the use of these molding materials is shown by sections through the castings, illustrated in Fig. 13. Measurements of casting diameter showed that expansion was greatest in green sand and least in cement molds (Fig. 14).

All these results indicate that the extent of casting expansion should be directly related to the volume of shrinkage in the casting. Such a relationship should be expected on fundamental grounds. Many of the experiments were performed using a gray flake graphite iron of constant composition poured at constand temperatures within the range 1500 C (2732 F) to 1200 C (2192 F). If the relationship between the mean casting diameter and volume of shrinkage defect is examined for a given pouring temperature, there is a significant correlation between these two factors, the volume of the shrinkage defect increasing as the casting expansion increased.

The relationships for pouring temperatures of 1400 C (2552 F) and 1300 C (2372 F) are shown in Fig. 15, and provide evidence that shrinkage is in fact directly related to casting expansion.

Nodular graphite irons present a more difficult problem. Experiments carried out on the soundness of nodular graphite irons have employed keel block castings, of the type shown in Fig. 16. This keel block was so designed that the keel section would be sound and adequately fed. In this casting all the shrinkage is concentrated in the feeder head, and the effects of the variables studied was shown in the residual unsoundness in the head.

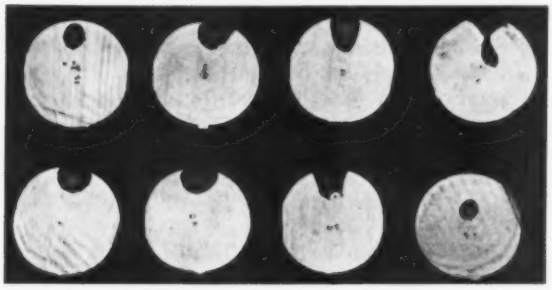
Keel blocks cast in green sand molds showed extensive casting expansion, and the feeder heads contained deep pipes and dispersed porosity. Increasing the mold rigidity by using hard rammed green sand or dry sand molds reduced the casting expansion and the volume of feeder head pipe. This suggested that

a relationship might exist between the amount of feed metal required as measured by the feeder head pipe volume and the casting expansion.

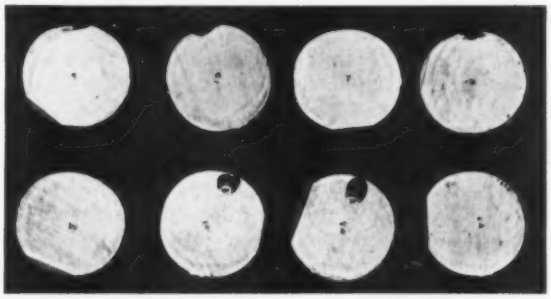
Experiments using a hypoeutectic nodular graphite iron of constant composition were extended to include a rigid cement sand mold, and comparable measurements of the casting expansion with feeder head pipe volume were made in a series of green and cement sand molds. Casting expansion was measured by comparing mold and casting dimensions at corresponding positions on the casting. Green sand molded castings showed a large net expansion relative to the original mold dimensions, while cement molded keel blocks contracted.

The mean changes in casting dimension relative to the mold, feeder head pipe volume, and casting weight are given in the table for the keel blocks cast in either green sand or cement sand molds.

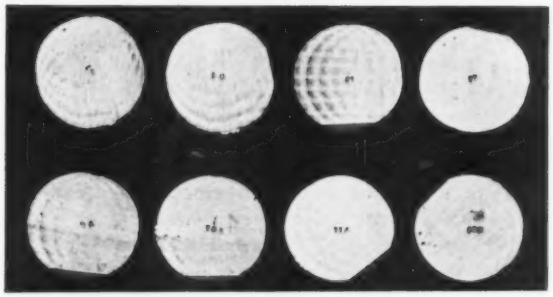
Sections through green sand and cement sand molded keel blocks of the same metal composition and pouring temperature are shown in Figs. 17 and 18, illustrating the expansion of the keel section in a green sand mold associated with gross shrinkage in the feeder head, and the improved dimensional accuracy and soundness obtained from a rigid cement sand mold. If the mean casting expansion or contraction relative to the original mold dimension for each of the keel blocks is plotted against volume of feeder head pipe, a linear relationship is obtained. This result is shown in Fig. 19 and confirms that



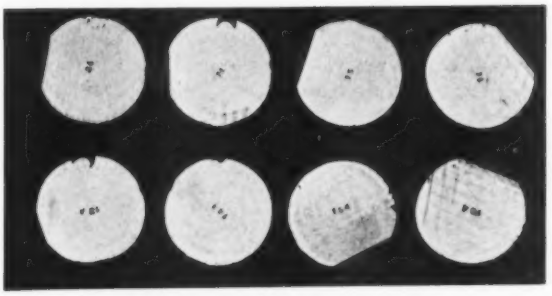
Cast in green sand molds



Cast in dry sand molds



Cast in CO_2 process molds



Cast in cement sand molds

1500 C (2732 F)	1400 C (2552 F)	1300 C (2372 F)	1200 C (2192 F)

Fig. 13 — Sections through 3 in. spherical flake graphite iron test castings. Pouring temperatures are shown under each column.

TABLE — CASTING DIMENSION MEAN CHANGES

Type of Mold	Mean Change in Casting Dimension Relative to Mold, in.	External Feeder Pipe Volume, cc	Casting Weight, lb
Green Sand	+0.095	99.3	45.2
Cement Sand	−0.051	16.9	43.8

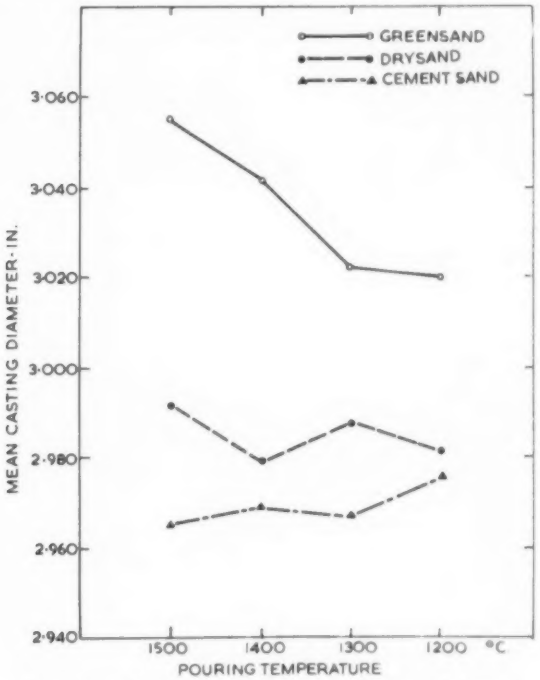


Fig. 14 — Comparison of mean diameters of hypoeutectic flake graphite spherical test castings poured in green sand, dry sand and cement sand molds over a temperature range of 1500-1200 C (2732-2192 F).

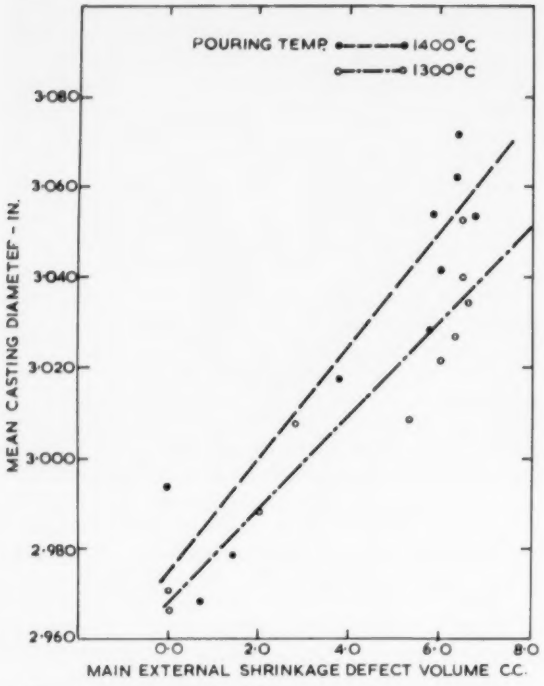


Fig. 15 — Relationship between mean casting diameter and volume of external shrinkage defect volume for 3 in. hypoeutectic flake graphite iron spheres cast in molds of different rigidity at 1400 C (2552 F) and 1300 C (2372 F).

for hypoeutectic nodular irons of fixed composition and pouring temperature, there is a strong positive correlation between casting expansion and feed metal requirements.

HOW EUTECTIC EXPANSION AFFECTS SOUNDNESS

The soundness of gray irons is intimately connected with the precipitation of graphite during eutectic solidification. This provides the expansion force which, under the correct conditions promotes soundness, or alternatively expands the casting and may result in unsoundness.

The proportion of eutectic which is present in the iron reaches a maximum value of unity when the carbon equivalent content, given by the formula C.E. % = Total Carbon % + ⅓ (Silicon % + Phosphorus %), reaches a value of 4.3 per cent.

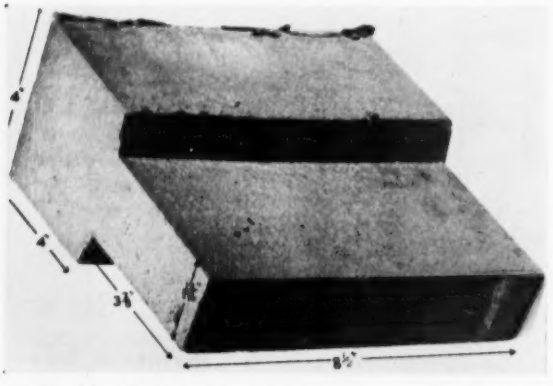


Fig. 16 — Design of keel block casting, showing principal dimensions.

The value given by this equation is only an approximation and the true value of the eutectic, over irons of a wide range of compositions, is in some doubt.[13] However, the proportion of graphite in the eutectic varies with the relative carbon, silicon and phosphorus contents, and should also reach a maximum value to provide maximum expansion.

In low phosphorus hypoeutectic irons, the eutectic graphite may be calculated from a knowledge of the iron-carbon-silicon system.[14] An alternative formula, used at the BCIRA, has been reported by Fuller:[15]

$$\text{Eutectic Graphite \%} = \frac{100(\text{Total Carbon \%} - 1.7 + 0.1\ \text{Silicon \%})}{(100 - 1.7 + 0.1\ \text{Silicon \%})}$$

In low phosphorus hypereutectic irons allowance must be made for the amount of graphite precipitated prior to the solidification of the eutectic when calculating the amount of eutectic graphite. For phosphoric irons other formulas have been proposed,[16] but lack of knowledge of the quantitative role of phosphorus in modifying the constitution of the system makes an accurate formula unobtainable at present, although variations in eutectic graphite with constant phosphorus content have been followed using formulas similar to that stated above.

In unfed castings of medium section thickness made in green sand, increasing the carbon equivalent content or the eutectic graphite content yields a more open grain, and castings become more prone to porosity as has been shown by Timmins[1] and by Jeffery and others.[17] This is believed to be due to the greater casting expansion with increase in eutectic graphite, as illustrated by Figs. 20 and 21, in which the size and the internal porosity, measured by Archimedes' principle, of 4 in. high by 4 in. diameter cylinders both increased with increase in eutectic graphite. These test castings contained 1 per cent phosphorus so that the comparative, but not the absolute values, of the eutectic graphite are valid.

On the other hand, it has been shown that the effect of increasing carbon equivalent or eutectic graphite is to promote soundness in light castings. It is believed that the reason for these contrary effects is the reduced extent of casting expansion in lighter-sectioned castings. The effect of increasing carbon equivalent in improving soundness in hypoeutectic irons has been shown by Gittus[18] employing K-bar castings, and by Hughes[19] for plates with bosses in which surface shrinkage defects occur beneath the bosses. This latter result is reproduced in Fig. 22, which also shows that the effect is reversed in hypereutectic irons.

EUTECTIC CELLS AFFECT SHRINKAGE

Solidification of the gray iron eutectic is initiated at a number of points or nuclei; subsequent solidification proceeds by growth from these centers.[20] The number of nuclei available for solidification can be varied in a given iron. The solidification process and

structure of the iron are considerably influenced by the degree of nucleation of the melt, and it is therefore not surprising that the shrinkage characteristic of an iron should be closely related to its degree of nucleation.

Each region of eutectic, consisting of graphite and austenite solidifying around a nucleus, is termed a eutectic cell, and by suitable etching of a microspecimen these eutectic cells may be revealed. Since each eutectic cell has grown from one nucleus, the number of eutectic cells gives a measure of the degree of nucleation of the melt.

It is a fact of repeated observation that, increasing the number of eutectic cells leads to an increase in unsoundness. The reason for this effect has not yet been fully established, but preliminary experiments suggest that increasing the number of eutectic cells growing leads to a small increase in casting expansion. This may result from changes in the solidification sequence.

The number of eutectic cells which grow may often be quite independent of the composition, and at constant pouring temperature and cooling rate is mainly governed by the treatment which the melt has received. The degree of nucleation of the melt may vary widely, and is probably more readily recognized by foundrymen as variations in the condition of the molten metal from time to time.

Variations in the degree of nucleation lead also to variations in chilling tendency and in mechanical strength. This difference in numbers of eutectic cells in different irons is sometimes recognized as differences in the grain of a casting when fractured. In polished samples, the eutectic cell number may be enumerated by etching and examination at low magnification, and this constitutes a useful form of control test for soundness.[21,22,24]

As an example, Fig. 23 illustrates the eutectic cell structure of a sound and a defective casting, made during the same day in a cylinder foundry. This figure shows that the unsound casting contains the largest number of eutectic cells.

Fig. 17 — Green sand molded nodular graphite iron keel block. Note swelling of keel section and gross cavity in head, in comparison with Fig. 18.

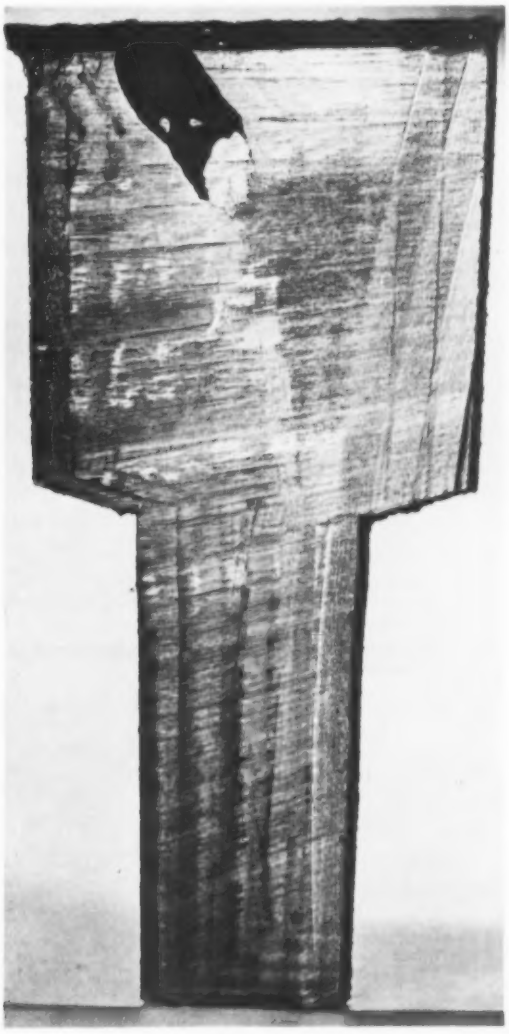


Fig. 18 — Cement molded nodular graphite keel block. Note presence of purged plug in head. Metal composition is similar to casting shown in Fig. 17.

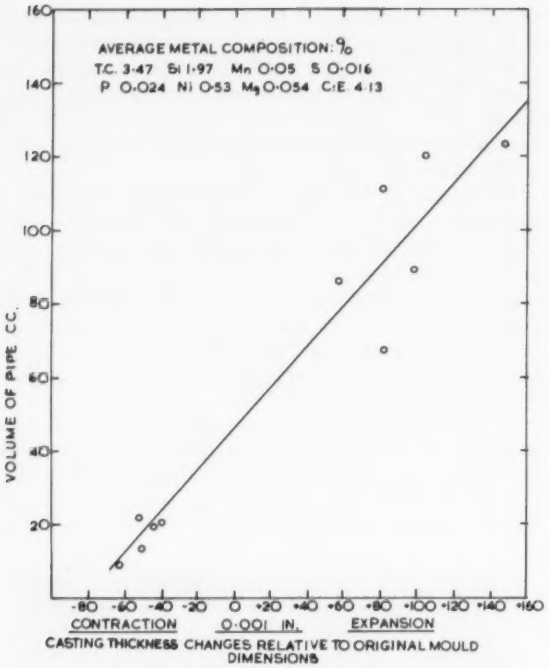

AVERAGE METAL COMPOSITION: %
T.C. 3·47 Si 1·97 Mn 0·05 S 0·016
P 0·024 Ni 0·53 Mg 0·054 C.E. 4·13
VOLUME OF PIPE C.C.
CONTRACTION
0·001 IN.
EXPANSION
CASTING THICKNESS CHANGES RELATIVE TO ORIGINAL MOULD DIMENSIONS

Fig. 19 — Green sand and cement sand molded nodular iron keel block casting expansions and contractions (relative to mold dimensions) vs. volume of pipe in feeder head.

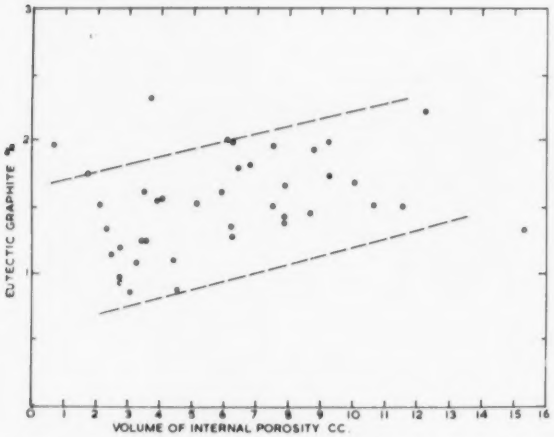


Fig. 21 — Eutectic graphite content and the volume of internal porosity.

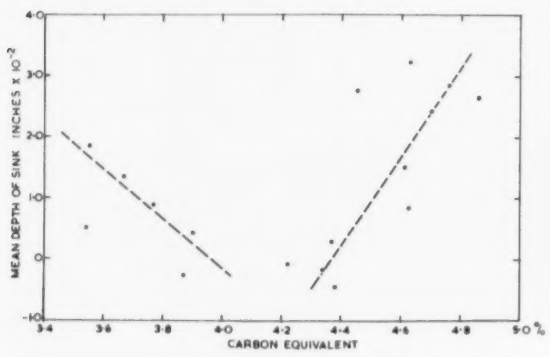


Fig. 22 — Relationship between depth of sink and carbon equivalent content for uninoculated thin plates.

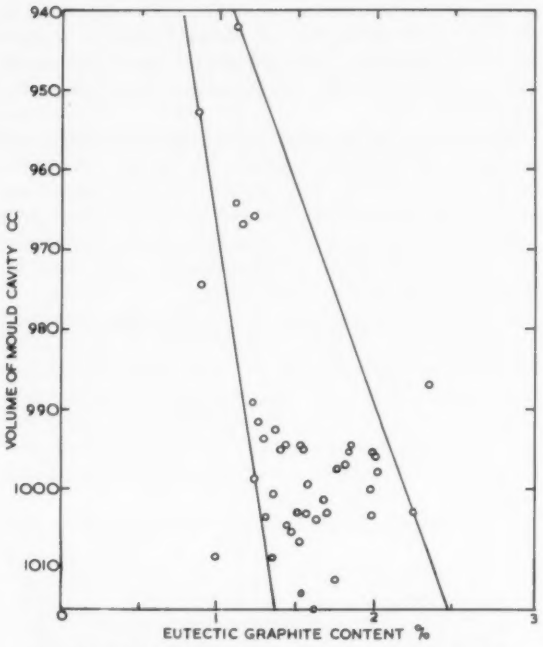


Fig. 20 — Volume of mold cavities and eutectic graphite content.

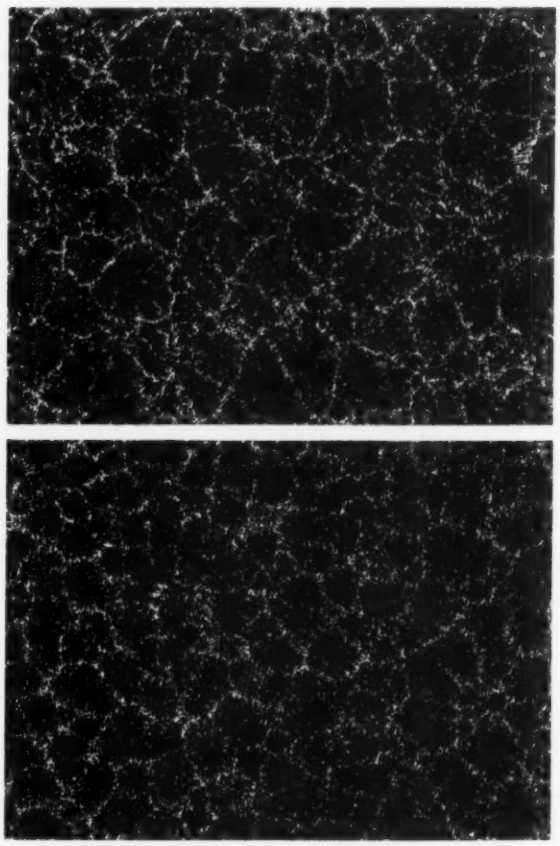


Fig. 23 — Difference in eutectic cell number in sound and defective casting. Sound casting (top) contained 530 cells per sq in.; unsound casting (bottom) contained 890 cells per sq in. Stead's reagent etch. 7 ×.

In an investigation carried out using a test casting which consisted of a plate 9 in. x 6 in. x $\frac{5}{16}$-in. thick on which were mounted two bosses each $1\frac{1}{4}$ in. diameter and 1 in. high (Fig. 24), it has been shown that there is a significant correlation between the number of eutectic cells growing in the iron and surface shrinkage (sinking) which occurs on the face of the casting at the points where the bosses are attached to the reversed side. Sinking increased as the number of eutectic cells increased (Fig. 25).

These results were obtained from experiments using batch furnaces in which the effect of variations in the manganese and sulfur contents of the iron, ladle inoculation with ferrosilicon, and melting history of iron upon sinking were determined using a basic metal composition of:

Total Carbon, %	3.1 – 3.3
Silicon, %	2.7 – 3.0
Manganese, %	0.7 – 0.8
Sulfur, %	0.07 – 0.09
Phosphorus, %	1.05 – 1.15

The composition of this iron is similiar to that employed in many British foundries producing light domestic-type castings.

VARIATIONS EFFECT IN THE IRON MELTING HISTORY

Superheating the melt and holding metal in the furnace are processes which reduce the degree of nucleation of the melt, and hence the number of eutectic cells which grow at a given pouring temperature.[23] A series of experiments[21] was carried out in which the surface shrinkage characteristics of an iron were examined at constant composition and constant pouring temperature. The iron had been superheated to temperatures within the range 1450 C - 1600 C (2642 F-2912 F), and held in the furnace for periods between zero and 30 min. Surface shrinkage decreased with increased furnace temperature, and increased furnace holding time (Fig. 26).

As a result of these observations, it may be predicted that the established preference for melting as hot as possible in cupola operation is consistent with

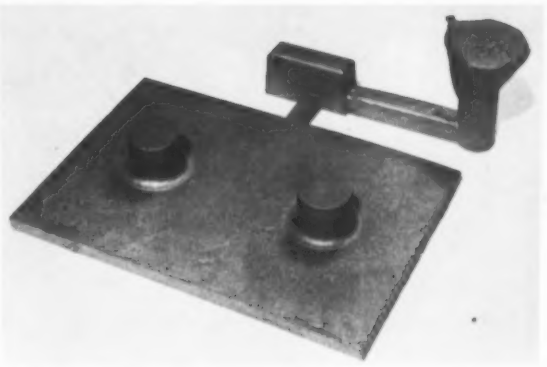


Fig. 24 — Design of plate with bosses test casting.

minimizing shrinkage defects, although this effect may in part be offset by increased contact with carbonaceous material when the higher melting temperature is obtained by increasing the coke charge. Holding the metal in a receiver or bull ladle at the spout of a cupola should tend to minimize shrinkage, since during this holding period the effect of inoculation will gradually fade and the degree of nucleation will be decreased.[24] In the case of a batch-type furnace, melting at a slow rate or holding for long periods are likely to promote soundness.

INOCULATION

Inoculation may be defined as; an addition to the molten iron of a relatively small amount of a substance having a powerful effect in increasing the degree of eutectic nucleation, and hence increasing the number of eutectic cells which grow. Such substances include graphite, coke and ferrosilicon. All iron melted in contact with carbonaceous material such as coke, as for instance in cupola melting, will to some extent be inoculated. The actual degree of inoculation depending upon the melting conditions, and the time of standing out of contact with inoculating materials during which period the inoculation effect wears off.

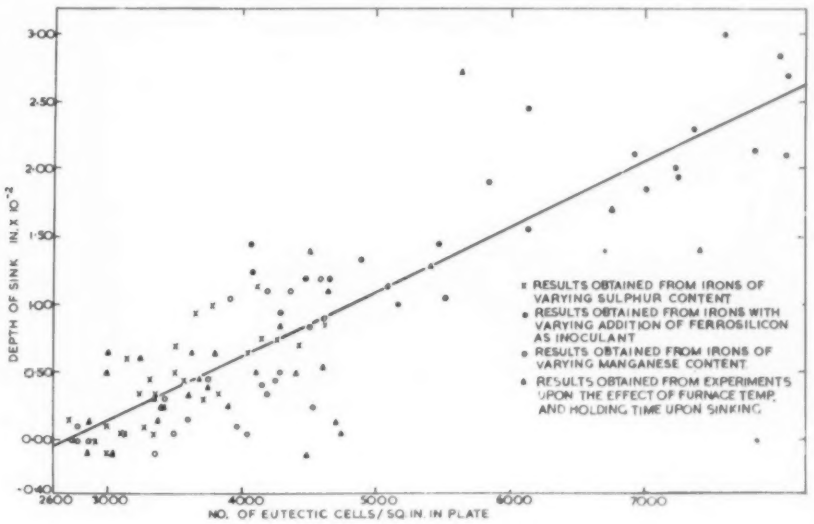


Fig. 25 — Relationship between depth of sink and combined effects of sulfur and manganese contents, ferrosilicon inoculant and furnace temperature and holding time on eutectic cell number.

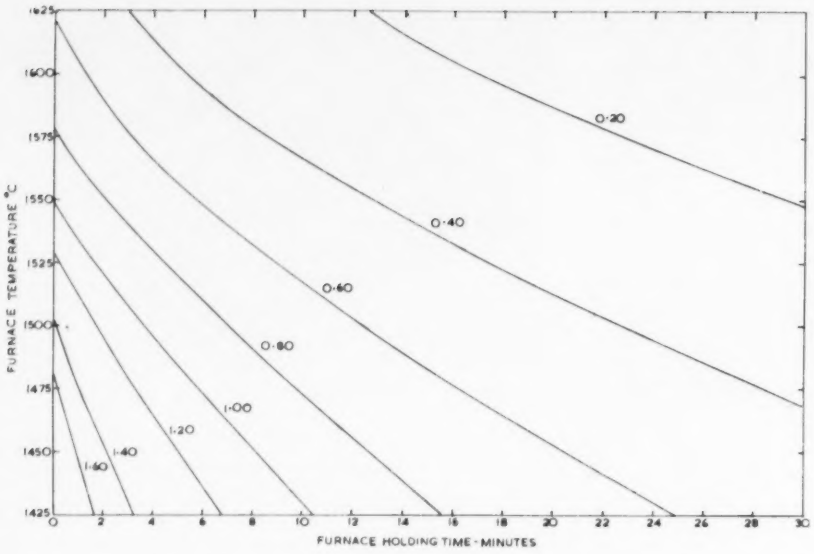


Fig. 26 — Relationship between furnace temperature, furnace holding time and observed depth of sink.

Similarly, metal which has been melted out of contact with materials known to have a graphitizing effect will be relatively uninoculated. This phenomenon has been clearly demonstrated in the laboratory, examples of uninoculated and inoculated irons etched to show their eutectic cell distribution being shown in Fig. 27. A quantitative relationship between the ferrosilicon increment, as an inoculant, the eutectic cell number and soundness has been demonstrated, and is illustrated in Fig. 28.

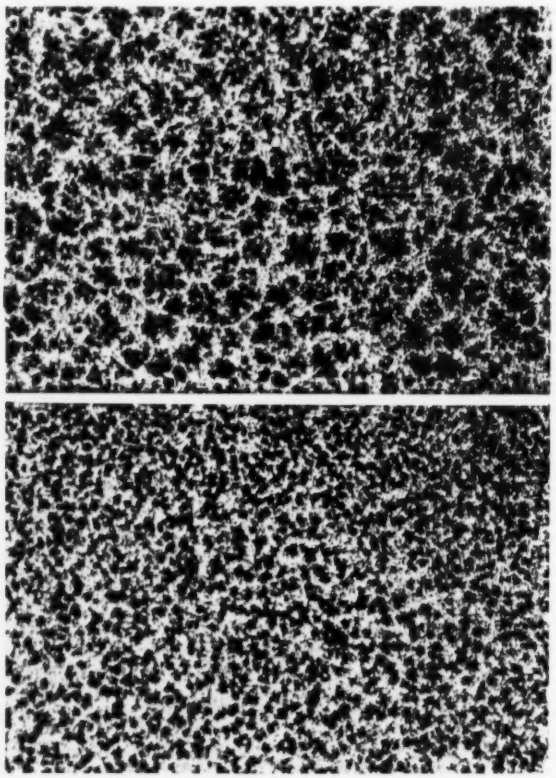


Fig. 27 — Effect of inoculation on the eutectic cell number. Uninoculated (top), eutectic cell number 3,900 per sq in.; inoculated (bottom), eutectic cell number 10,200 per sq in. 5 per cent aq. ammonium persulfate etch. 12 ×.

In British practice, deliberate inoculation is not generally employed except for the production of high duty irons of low carbon equivalent value. Such irons possess relatively high shrinkage, and an increase in shrinkage due to inoculation will probably not be important since feeding would normally be practiced.

Some processes such as recarburization, desulfur-

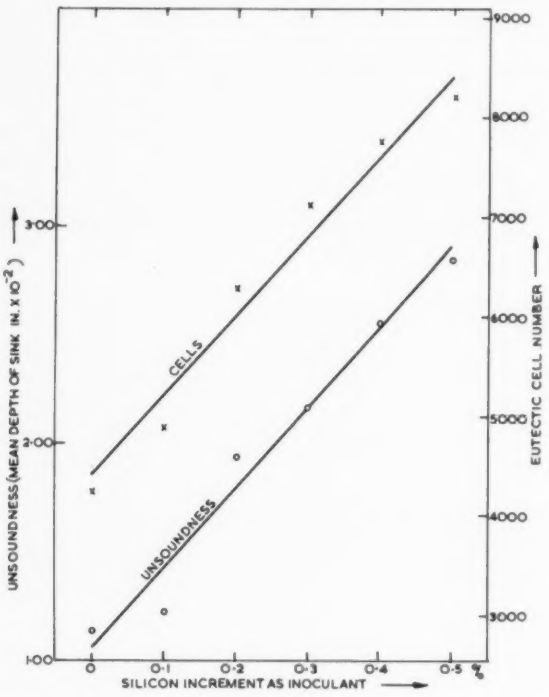


Fig. 28 — Relationship between silicon increment (ferrosilicon 80 per cent silicon) as inoculant, eutectic cell number and unsoundness.

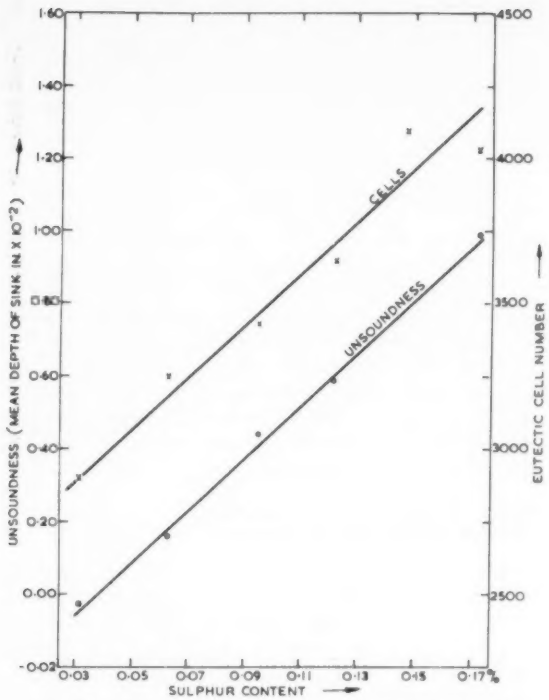


Fig. 29 — Relationship between sulfur content, eutectic cell number and unsoundness.

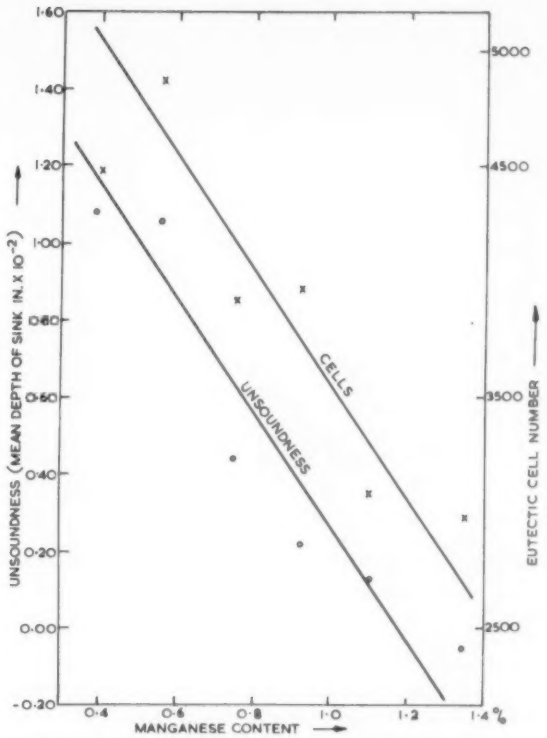


Fig. 30 — Relationship between manganese content, eutectic cell number and unsoundness.

ization and resiliconization, which involve the injection of materials into the iron, will increase considerably the degree of nucleation and will promote unsoundness. On the contrary, an addition of titanium followed by bubbling either carbon dioxide or argon through the metal in the ladle, which has been shown by Timmins[1] to promote soundness, is also explicable in terms of the effect upon the number of eutectic cells growing. This latter process considerably reduces the degree of nucleation of the melt.

SULFUR AND MANGANESE EFFECT

Increasing the sulfur content of liquid iron causes an increase in shrinkage unsoundness. This is accompanied by an increase in the degree of nucleation measured by the number of eutectic cells, as is shown in Fig. 29. Manganese, on the other hand, tends to decrease the number of eutectic cells and to increase soundness, as shown by Fig. 30. This effect has been established in the laboratory and in the foundry, where increasing the manganese content has been shown to reduce sinking and drawing defects in light castings.[8] Although it is difficult to distinguish cause and effect, it is at present believed that manganese has its effect by the progressive neutralization of sulfur in solution according to the reversible reaction:

$$Mn + FeS \rightleftharpoons MnS + Fe$$

EUTECTIC NUCLEATION ROLE IN THE FOUNDRY

Variations in the degree of eutectic nucleation (state of inoculation) are probably one of the major factors affecting shrinkage characteristics within the foundry and, until recently, certainly the least suspected. As a result of laboratory experiments, it was believed that variations in the condition of the metal due to variations in cupola operation, and delays in casting metal during the course of the day, might account for otherwise inexplicable variations in the shrinkage characteristics of an iron of approximately constant composition produced in foundries.

Variations in the degree of nucleation of iron produced from a hot-blast cupola during the course of a day[2,4] are shown in Fig. 31. The decreased eutectic cell number associated with metal, obtained from a continously tapped cupola shortly after the tap hole was opened, supports the opinion often expressed by

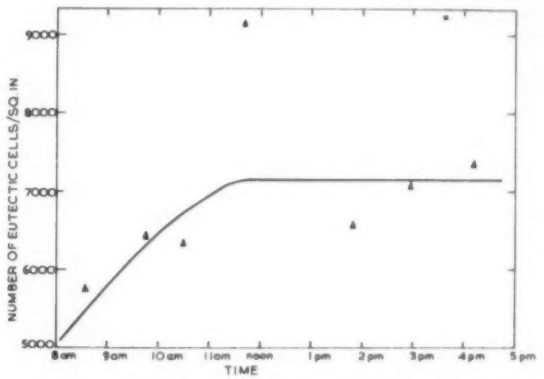


Fig. 31 — Variations in the mean eutectic cell number per sq in. with time, using metal from the bull ladle at the spout of the hot-blast cupola.

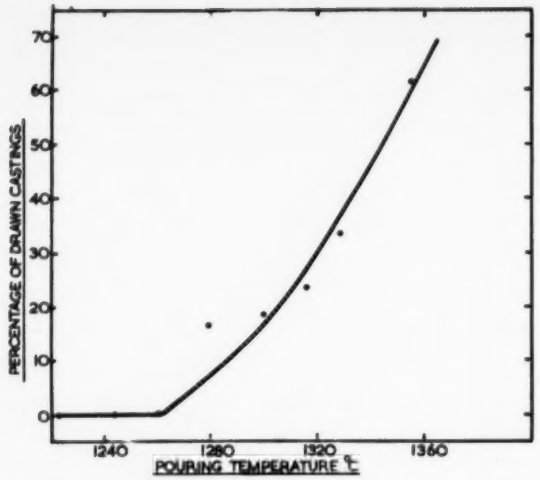


Fig. 32 — Effect of pouring temperature on the incidence of drawing defects in light castings.

foundrymen that this metal differs fundamentally from that produced later in the day. This low eutectic cell number may be associated with outbreaks of chill or of phosphide exudation defects in high phosphorus irons which have been reported from time to time to occur early in the day in certain foundries, since laboratory experiments have indicated that these defects only occur in irons in which the number of eutectic cells growing is low. Throughout the course of the day there was a strong correlation between the degree of nucleation of the iron and the amount of shrinkage which occurred.

Variations in the state of inoculation in the foundry may arise from a wide variety of causes, some of which may involve variations in practice such as cooling some ladles of metal by adding lumps of pig iron. This treatment would produce an iron of a higher state of inoculation, and a greater shrinkage tendency, than one which was allowed to cool in the ladle normally. Similar variations in the temperatures of the iron tapped from two cupolas may affect soundness, not only due to variations in the melting conditions within the cupolas, but also because iron produced in the cupola which was running hotter would require a greater standing time, during which the degree of nucleation decreases, before a given casting temperature is obtained.

The eutectic cell number in an iron is not necessarily reflected in the flake graphite structure,[24] and for this reason metallographic examination to compare sound and defective castings should pay particular attention to the eutectic cell structure at comparable points in the castings.

POURING TEMPERATURE AFFECTS MOLD CAVITY MOVEMENT AND EUTECTIC CELLS

Shrinkage defects in gray irons are considerably influenced by pouring temperature, although the optimum temperature depends to a large extent upon the nature of the casting and the type of mold, with the consequence that early authorities were not always in agreement. In K-bar test castings molded in green sand, the occurrence of internal porosity at hot spots increased with an increase in pouring temperature.[8] On the other hand, unfed green sand molded castings generally show an increase in external top surface shrinkage of the shallow sink type at the lowest pouring temperatures, although this form of shrinkage is no guide to internal porosity.

Drawing and piping defects at hot spots are, however, related to internal porosity, and Fig. 32 shows how rapidly the incidence of these defects increased for a specific casting on a production line when the pouring temperature exceeded 1260 C (2300 F).[7] The occurrence of piping with increasing pouring temperature has been confirmed in green sand unfed spherical test castings, the severity of the defect increasing with progressive rise of pouring temperature.[10] A converse effect of pouring temperature has been observed in rigidly molded castings for reasons which are explained below.

MOLD RIGIDITY AND POURING TEMPERATURE RELATIONSHIP

The extent of casting expansion due to mold cavity dilation depends upon the pouring temperature, as is illustrated by the behavior of 3 in. diameter flake and nodular graphite iron spherical castings made in molds of varying rigidity.[10] Green sand, dry sand, CO_2 process and cement sand molds have been employed in experiments in which the pouring temperature was varied over the range 1375 C - 1200 C (2507 F - 2192 F). The effects of pouring temperature upon casting size, weight and shrinkage volume, were observed for each type of mold.

Pronounced trends were obtained for green sand, CO_2 process and cement sand molds, but no consistent trend was observed for dry sand molds. Green sand molded castings increased in mean diameter and weight with increasing pouring temperature, as shown in Fig. 33, whereas castings made in CO_2 process molds behaved conversely, diameter and weight decreasing with increasing pouring temperature, as shown in Fig. 34. Cement sand molds showed the same trend as CO_2 process molds.

Gittus' work[2] provides an explanation of the influence of pouring temperature upon casting size, at least in green sand molds. If a green sand mold cavity increases in volume when filled with molten metal as a result of the heating of the sand, it is probable that this expansion is time dependent—the hotter the metal entering the mold, the greater will be this expansion of the mold cavity before the casting solidifies and is no longer able to follow changes in the mold cavity volume.

Increasing the pouring temperature also delays the process of solidification. Quenching and thermal analysis of 2 in. diameter bars of a hypoeutectic flake graphite iron at various stages of solidification has clearly demonstrated this effect of pouring temperature, as illustrated in Fig. 35.

Rigid mold materials, such as CO_2 process and cement sand, are believed to expand on heating, causing an inward movement of the mold walls and thus reducing the volume of the mold cavity before solidification of the casting is complete.

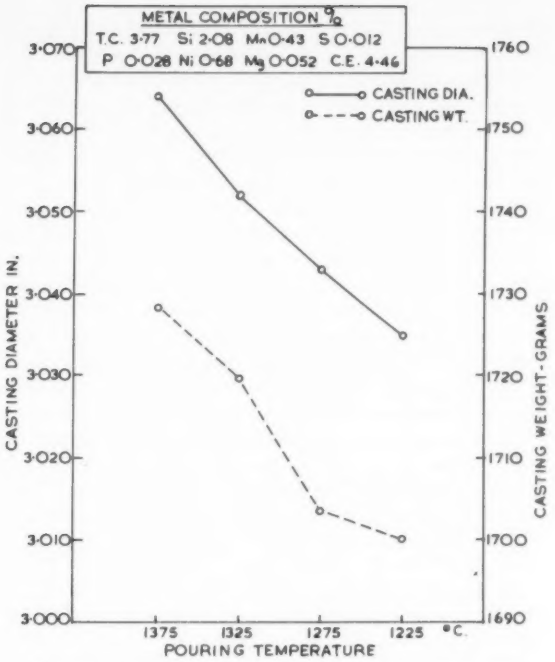


Fig. 33 — Green sand molds: casting diameter and weight vs. pouring temperature.

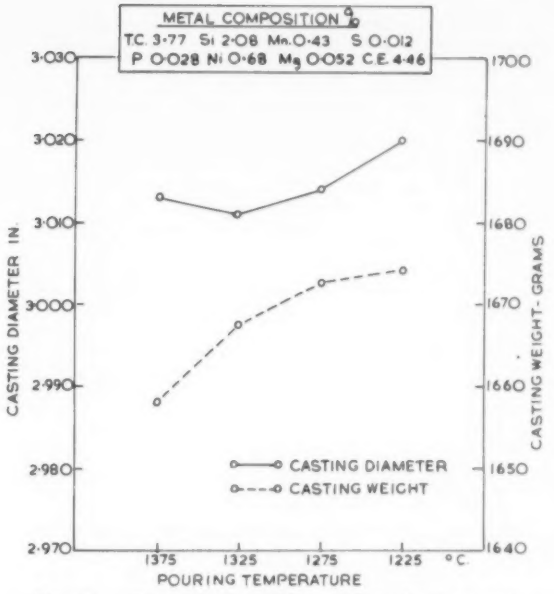


Fig. 34 — CO_2 process molds: casting diameter and weight vs. pouring temperature.

Therefore, the longer complete solidification is delayed by hot pouring, the less will be the casting size and the sounder the casting in these molds. Gittus suggested that in ordinary dry sand the mold cavity decreased when heated by metal.[2] However, further experiments[10] have shown that this effect only becomes pronounced in most rigid molds, and that dry sand molds are usually intermediate in behavior.

Nevertheless, foundry experience has shown[7] that sounder castings are sometimes obtained in dry sand molds when the iron is poured hot. In practice, the correct pouring temperature to minimize shrinkage defects will depend upon the molding procedure employed, and will be lower for green sand molded castings than for castings poured in more rigid molds.

POURING TEMPERATURE AND EUTECTIC CELLS

For an iron of a given degree of nucleation, decreasing the pouring temperature or increasing the cooling rate in the mold will increase the number of eutectic cells growing. This increase is relatively small at high pouring temperatures, but is most pronounced at low pouring temperature (Fig. 36). This increase in cell number may be associated with a sharp increase in unsoundness at low pouring temperatures. This is shown in Fig. 37, in which it is seen that below 1320 C (2408 F) sinking under bosses increased as pouring temperature decreased.

Above 1320 C (2408 F), however, the dominant effect was that of pouring temperature on the mold, and sinking increased slightly with pouring temperature. It would be expected that increasing the pouring temperature would lead to an increase in the inherent tendency of the metal to produce sound castings, due to a reduction in the number of eutectic cells growing. However, in green sand molds, it appears that the contrary influence of increasing pouring temperature in causing mold cavity expansion is generally the overriding feature. In the more rigid molds, however, the effect of pouring temperature upon the mold leads to greater soundness with increased pouring temperature, as described earlier. No doubt this effect is strengthened by the simultaneous decrease in the number of eutectic cells growing.

Whether or not a casting made in a particular iron will be sound depends upon its design as much as

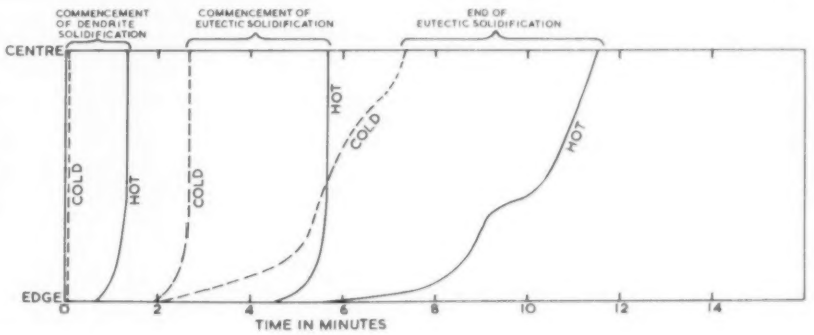


Fig. 35 — Pouring temperature variations effect on the solidification sequence of a 2 in. diameter bar of a low phosphorus hypoeutectic flake graphite iron.

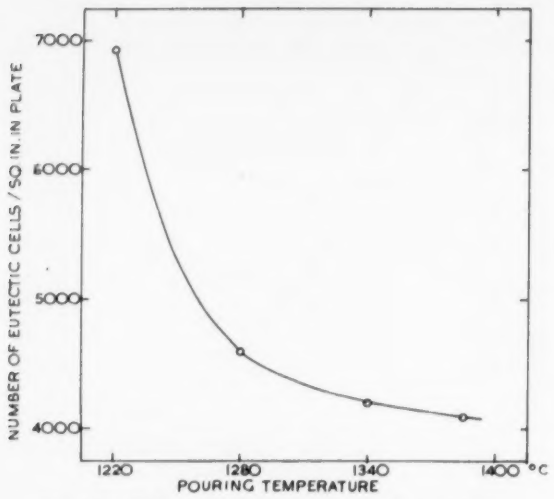


Fig. 36 — Relationship between pouring temperature and the number of eutectic cells growing.

upon the other factors reported. Normally, the design of a given casting is not a variable, although, due to human factors, small variations such as in the thickness may occur with unfortunate results, as is instanced by the brake-drum castings referred to earlier. A further example of the effect of small variations in the dimensions of a casting upon soundness is illustrated by experiments using plate-with-bosses test castings.[25]

GOOD DESIGN AND GATING IMPROVE SOUNDNESS

It was observed that increasing the plate thickness by $\frac{1}{32}$-in. increased the depth of sink beneath the bosses by approximately 0.001 in. This is large compared with the depth of sink of 0.005 in. which was arbitrarily concluded in earlier work upon surface shrinkage defects to render a casting unsatisfactory, particularly if it were to be subsequently enamelled.[26]

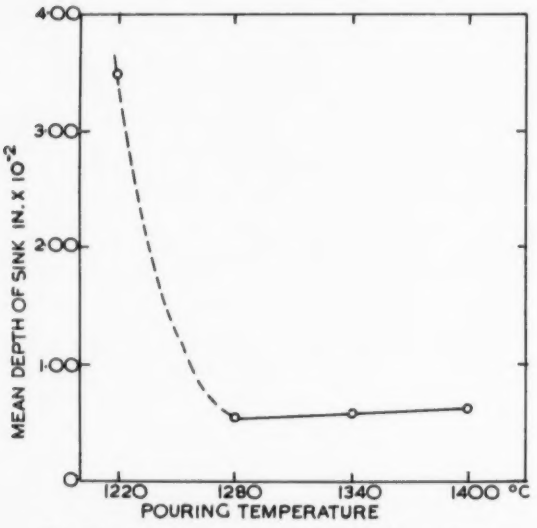


Fig. 37 — Pouring temperature variations effect on sinking.

Differences in thickness of this magnitude may result from rapping the pattern during removal from the mold; small variations in practice of this nature may account for sporadic outbreaks of shrinkage defects.

It is common experience that a particular design of casting in a foundry is more prone to exhibit shrinkage defects than other designs of casting on the produce line produced under similar conditions. Such castings are particularly sensitive to small changes in metal composition and foundry practice. This effect has been shown in the laboratory[27] where K-bar test castings of a certain size were more prone to drawing defects than those of either larger or smaller size. This result is illustrated in Fig. 38. Similar experiences are often reported from foundries making a given casting in a wide range of sizes.

In general, increasing the surface area/volume ratio of green sand molded castings causes a decrease in internal shrinkage, as has been illustrated by Timmins[1] and Szajda.[27] This effect is thought to be due to the lower amount of heat delivered to the mold per unit of casting surface area.

Gating plays an important part in the production of sound castings. Although a considerable amount of research work has been carried out to determine hydraulic factors affecting metal flow through a gating system and the principles of metal flow are well understood,[28] little work has been published upon the influence of the gating system upon the soundness of gray iron castings. Experiments so far[25] have shown that for plate castings bearing bosses it is an advantage to use a stoppered sprue, and a large runner: sprue ratio is desirable, as shown in Fig. 39. Slight pressurization is an advantage.

There is an interaction between the gating system as a whole and soundness, and although the effect of the individual components may be isolated, the most important aspect is the combined effect of all

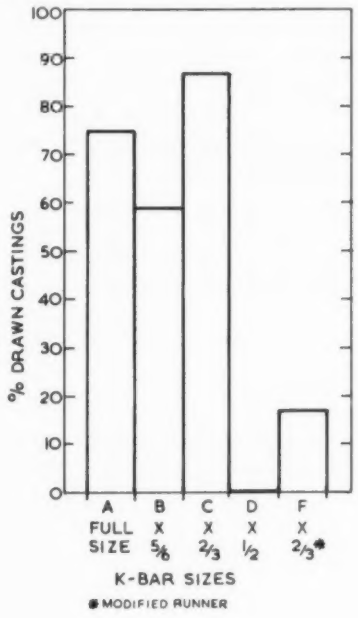


Fig. 38 — Incidence of drawing in K-bar test pieces varying with size and design of casting.

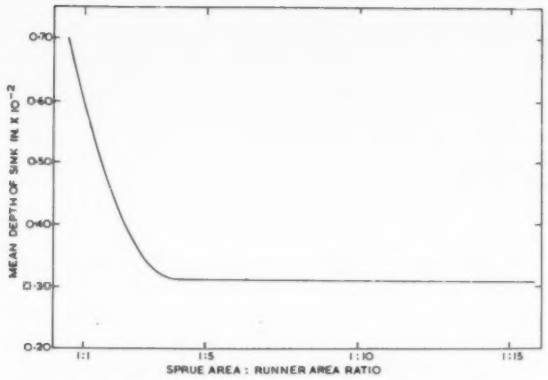


Fig. 39 — Sprue area: runner area ratio associated with minimum sinking at a number of gating ratios. Data abstracted from experimental results.

the variables. This result is at variance with the opinion of some other workers, who suggest that the type of gating employed for iron castings is unimportant provided that the inflow velocities are not sufficiently excessive to cause deterioration of the mold. In general, the commonly recommended gating ratios of the order of 1:1:<1 are not the best for avoiding sinking in this type of casting, and ratios of 1:4:0.5 or 1:5:1 have proved satisfactory. Such systems are slightly pressurized when head losses are considered.

When several castings are made from the same runner they are likely to be different, unless the system is perfectly symmetrical with regard to metal flow. The soundness of castings made as a spray about a long runner will vary considerably according to their relative positions with respect to the sprue.

All variables of design and gating are believed to influence temperature distribution within the casting, and so cause variations in soundness in much the same way as variations in pouring temperature. It is considered that, for flake graphite irons, the gating arrangement and the design of the casting should be such that a uniform temperature distribution is obtained throughout the casting to promote nondirectional solidification.

This leads to the conclusion that it is undesirable for more metal than is necessary to flow through a casting, and gating such that metal flows through one casting to reach another is definitely bad practice. On the other hand, for light-section castings, the use of flowoffs to prevent the first cold metal from entering the mold may not only help to avert cold shuts but may also greatly improve soundness.

ACKNOWLEDGMENT

The authors wish to thank the Director and Council of the British Cast Iron Research Association for permission to publish this paper.

REFERENCES

1. Timmins, A. A., "Some Factors Affecting the Formation of Shrinkage Defects in Cast Iron," *B.C.I.R.A. Journal of Research and Development, vol. 2*, Oct., pp. 19-36, Dec., pp. 47-62, 1947.
2. Gittus, J. H., "The Influence of Mould Factors on Casting Defects," *B.C.I.R.A. Journal of Research and Development, vol. 5*, April, pp. 264-277, 1954.
3. Hughes, I. C. H., "Solidification Sequences and Their Significance," *B.C.I.R.A. Journal of Research and Development, vol. 5*, Feb., pp. 518-536, 1955.
4. Gittus, J. H., and Hughes, I. C. H., "The Solidification of Castings in Relation to their Soundness," *B.C.I.R.A. Journal of Research and Development, vol. 5*, Feb., pp. 537-554, 1955.
5. Fuller, A. G., and Hughes, I. C. H., "A Study of the Solidification Process in Grey and White Irons," *B.C.I.R.A. Journal of Research and Development, vol. 7*, Aug., pp. 288-298, 1958.
6. Gittus, J. H., "Formation of Shrinkage Defects in Grey Iron Castings: Influence of the Mould," *Iron and Steel, vol. 28*, July, pp. 331-335, Aug., pp. 387-390, 1955.
7. Nicholas, K. E. L., and Hughes, I. C. H., "Some Physical Factors Influencing Shrinkage and Porosity in Grey Iron Castings," *British Foundryman, vol. 51*, Sept., pp. 428-435, 1958.
8. Hughes, I. C. H., and Gittus, J. H., "Shrinkage Defects in Grey Iron Castings," *Foundry Trade Journal, vol. 101*, July 19, pp. 71-83, 1956.
9. Saeger, C. M., and Ash, E. J., "Properties of Gray Cast Iron as Affected by Casting Conditions," AFA TRANSACTIONS, *vol. 41*, pp. 449-468, 1933.
10. Nicholas, K. E. L., "The Effects of Mould Rigidity, Moulding Sand Properties and Pouring Temperature on the Soundness of Unfed Grey Iron Castings," *B.C.I.R.A. Journal of Research and Development, vol. 7*, Dec. 1958.
11. Womochel, H. L., and Sigerfoos, C. C., "Influence of the Mold on Shrinkage in Ferrous Castings," AFS TRANSACTIONS, *vol. 48*, pp. 591-618, discussion, pp. 619-622, 1940.
12. Wallace, J. F., and Evans, E. B., "Risering of Gray Iron Castings," AFS TRANSACTIONS, *vol. 66*, pp. 49-55, 1958.
13. Piwowarsky, E., *Hochwertiges Gusseisen*, Springer-Verlag, Berlin, 1070 pp., especially Chapter 8, 1958.
14. Schmidt, W. A., Sullivan E., and Taylor, H. F., "Risering of Gray Iron Castings: Progress Report No. 5," AFS TRANSACTIONS, *vol. 62*, pp. 70-77, 1954.
15. Fuller, A. G., "The Soundness of Grey and Nodular Iron Castings," *B.C.I.R.A. Bulletin and Foundry Abstracts, vol. 14*, Nov., pp. 569-574, 1958.
16. Wittmoser, A., Krall, H. A., and Hutter, L., "Testing Cast Iron for Shrinkage Cavities," *Giesserei, vol. 43*, Aug. 2, pp. 409-418, in German, 1956.
17. Jeffery, W. C., Langner, E. E., Mitchell, W. G., and Azizi, G. D., "Relationship of Carbon Equivalent to the Properties of Cast Iron," AFS TRANSACTIONS, *vol. 62*, pp. 568-577, discussion, pp. 577-578, 1954.
18. Gittus, J. H., "Shrinkage Defects in K-bar Test Castings," *B.C.I.R.A. Journal of Research and Development, vol. 6*, Feb., pp. 456-483, 1957.
19. Hughes, I. C. H., "Surface Sinking Defects in Grey Iron Light Castings," *British Foundryman, vol. 50*, April, pp. 202-210, discussion, Oct., pp. 520-524, 1957.
20. Morrogh, H., "The Problem of Grain Size in Cast Iron," *British Foundryman, vol. 51*, Nov., pp. 588-591, 1958.
21. Fuller, A. G., "Further Studies on Some Factors Influencing Sinking under Bosses on Thin Plates: The Role of Eutectic Nucleation," *B.C.I.R.A. Journal of Research and Development, vol. 7*, Feb., pp. 157-170, 1958.
22. Fuller, A. G., paper to be published in *British Foundryman*.
23. Rickard, J., "A Note on the Influence of Furnace Holding Time on Chill and Mottle Formation," *B.C.I.R.A. Journal of Research and Development, vol. 7*, Aug., pp. 23-26, 1957.
24. Dews, J. W., and Fuller, A. G., "Sinking Under Bosses on Thin Plates: A Study of the Role of Nucleation in the Foundry," *B.C.I.R.A. Journal of Research and Development, vol. 7*, Dec., 1958.
25. Fuller, A. G., "The Effect of Design Variables Upon Shrinkage Defects under Bosses on Thin Plates," *B.C.I.R.A. Journal of Research and Development, vol. 7*, Oct., pp. 54-67, 1957.
26. Hughes, I.C.H., "Sinking under Bosses on Thin Plates: Preliminary Experiments on Foundry Variables," *B.C.I.R.A. Journal of Research and Development, vol. 5*, April, pp. 616-627, 1955.
27. Szajda, T. J., "Effect of the Size of K-bar Test Castings on Their Shrinkage Defects," *B.C.I.R.A. Journal of Research and Development, vol. 7*, Dec., pp. 110-128, 1957.
28. Ruddle, R. W., *The Running and Gating of Castings: A Review of the Literature*, Institute of Metals, London, 183 pp, 1956.

BENDING TECHNIQUES FOR EVALUATION OF CAST MATERIALS AND STRUCTURES

a preliminary appraisal

By J. C. Graddy

ABSTRACT

The accepted practices of inspecting the mechanical properties of castings are reviewed and found wanting. Three examples are given of parts that were weaker when made of high tensile strength material than when made of material of lower tensile strength. Therefore, bending tests are investigated to obtain a truer picture of structural behavior.

A cast bending specimen is described, and the test results for 28 different conditions of chemistry and heat treatment in aluminum and magnesium alloy are given. A machined bending bar is described and its results on the 28 different conditions are given. A study of the effect of geometry on bending modulus of rupture specimens of wrought materials is described and the results given.

A "shape of the curve" parameter for acceptability of bending specimens is offered and future work on bend testing is proposed.

TEST METHODS REVIEW

Inspection for specification mechanical properties in the alloys of aluminum and magnesium has been predominantly by tests of "cast-to-size" tensile specimens. These are produced by a gating system that is controlled by a specification standard. The casting specifications acknowledge the difference in the mechanical properties of these cast-to-size bars and of bars machined from the casting. This difference has led to the accepted practice of using a "casting factor" to reduce the specification mechanical properties for design use.

The writer believes that the cast-to-size test bar is a measure of the chemistry balance, melting practice and heat treatment of the test bar itself. It is a useful tool for foundry process control, but it is practically worthless as a measure of the mechanical properties contained in the cast structure.

Some investment foundries have even gated directly into the gage length of the cast-to-size bar. This makes the procedure a complete farce from an inspection viewpoint because of the excessive risered surface.

The ferrous foundries have adopted a method of separately casting a keel block from which tensile specimens are machined. This block is grossly overrisered when compared to the casting it is supposed to represent. Hence it is of even less value as an inspection method than the cast-to-size bars.

In the past, the Air Force required static testing to destruction of three castings from the first production lot. This was done to establish an acceptable quality level for radiographic inspection. Test engineers of the author's company added the practice of cutting a tensile specimen from the failed casting. The tensile strength values obtained were then used as a leveling factor for the static test results. This was always done if the results were higher than specification properties.

About three years ago the author's company began to specify that a tensile specimen be machined from a critical area of production castings on a sampling basis. The composition of the casting lot was carefully limited to insure a representative sample for inspection. The testing of machined tensile specimens, combined with the control of lot composition, is probably the first valid method for inspection of mechanical properties of cast structures.

During this same period they developed a beam-type casting for a critical structural application. A destruction test of a sample beam from each lot was selected as the best inspection method to determine bending behavior. In this particular casting, this test also proved cheaper than machining tensile specimens from the casting.

A destruction-type test can only be used on a sample plan. It can be an expensive method unless both the machining to prepare the rough casting and the loading system are simple.

TENSILE TESTS MAY BE MISLEADING

Most cast structures must be able to withstand bending loads. However, they are usually a complex shape with corners or notches in the load paths of the structure. Mechanical properties of tensile specimens have been used for design because these are the only properties given in the specifications.

Comparative tests show that material having a higher tensile strength is often weaker in the actual part than a lower strength material when the part has a high mechanical notch factor.

Figure 1 shows a comparison of aluminum alloys A356 and C355 in a threaded tubular joint under a

J. C. GRADDY is Prod. Design Eng., Douglas Aircraft Co., Missiles and Space Systems, Santa Monica, Calif.

bending moment. The static tensile strength of C355 alloy is 20 per cent greater than A356, but the cast part is actually 20 per cent weaker when made of C355 than when made of A356.

Figure 2 shows a comparison of A356 and C355 in the beam casting mentioned above. This shape is much less severely notched than the threaded joint of Fig. 1, however again the part made of the stronger alloy (C355) was weaker than the part made of the weaker alloy (A356).

The beam casting of Fig. 2 was placed in production, and a group of 40 test castings was ordered to determine production variability and to predict a minimum margin of safety for the structure. The production variability was accomplished by using four different melts of metal, and then some of each of the four melts were assembled into three heat treating furnace loads.

Table 1 shows the strength of the castings and the mean for each condition. A statistical analysis of the test indicates that heat treatment variations (in the same heat treat schedule) are 1½ times as significant as chemistry in producing a maximum strength casting. These castings, were produced under carefully controlled conditions, and two tensile specimens were cut from an extra casting of each melt. The tensile tests showed a range of 1.6 per cent, while the beam bending showed a range of 13.9 per cent.

During the two years the beam casting has been in large production, records have been kept of the acceptance tests. Figure 3 shows the load distribution of the production bend samples of this casting with the load distribution of the 40 test castings superimposed. Production acceptance bend samples plotted against the tensile samples which were cut by the foundry to monitor the heat treating operation are shown in Fig. 4.

Figure 5 shows the static test results of an investment cast lug of 4340 alloy steel heat treated to two levels of tensile strength. The 125,000 psi level had a mean static strength 14 per cent higher than the 160,000 psi castings. The range of failure load of the 175,000 psi parts was 2½ times the range of the 125,000 psi casting.

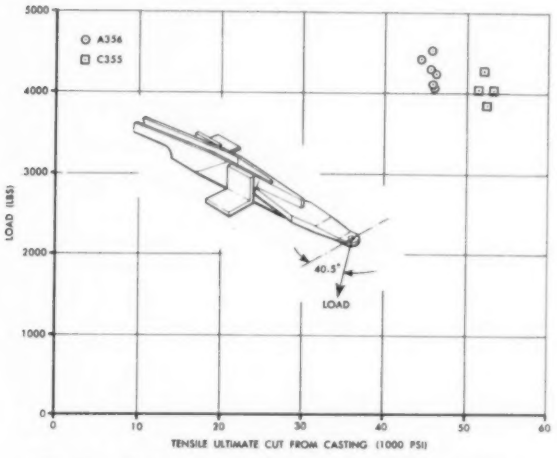


Fig. 2 — Comparison of A356 and C355 tests for a beam casting.

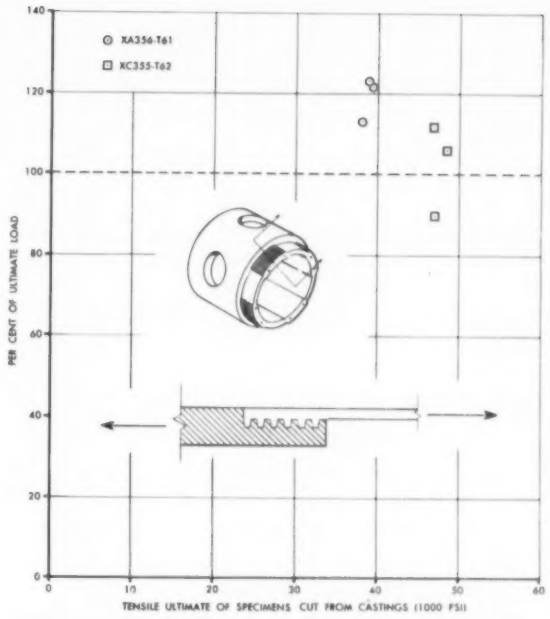


Fig. 1 — Comparison of aluminum alloys A356 and C355 tests for a threaded tubular joint.

TABLE 1 — BEND TESTS OF CONTROLLED TEST LOT OF BEAM CASTING

Heat Treat Lot	Chemistry Lot A	B	C	D	Mean
I	5360	5000	5360	5080	
	5200	5080	5360	5160	5153
	5160	4920	5350	4800	
II	5360	5480	5560	5400	
	5160	4960	5520	5320	5320
	5040	5120	5640	5280	
III	4920	4960	5120	5160	
	5120	5080	5350	5040	5101
	5160	5160	5020	5080	
Mean	5164	5084	5369	5147	

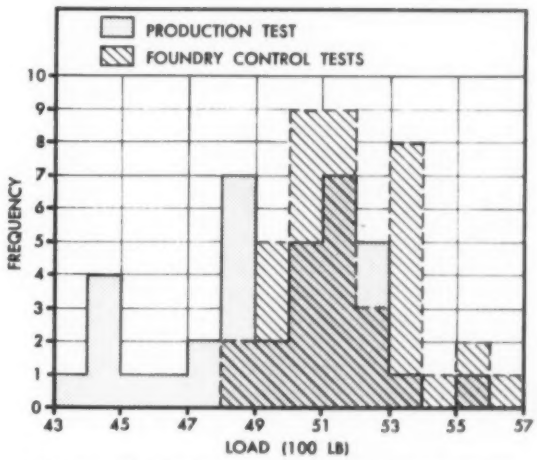


Fig. 3 — Distribution of strength tests of beam casting. The load distributions of the 40 test castings are superimposed.

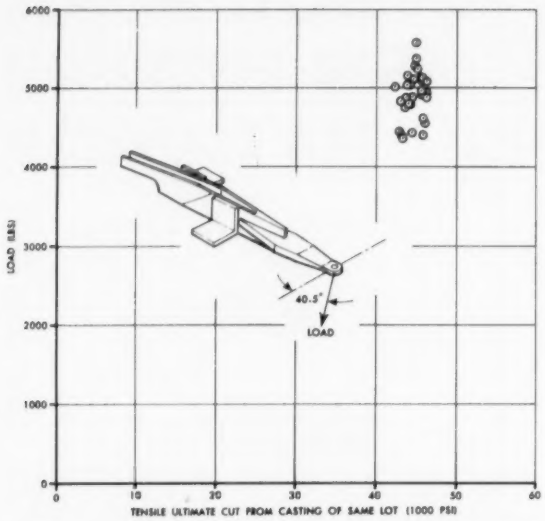


Fig. 4 — Sample bending vs. tensile test lot beam casting.

BENDING TEST SPECIMENS

These examples indicate that bending strength is not necessarily proportional to tensile strength in castings, and that some investigation should be made. To accomplish this, a cast-to-size specimen was designed incorporating notched load path as severe as had been present in many past designs. The casting was designed as an "H" section, and the pattern was made with matching iron chills and boxes for sand cores at the critical bending area. The combination of chills and sand cores made it possible to study the effect of chilling on bending strength with a minimum of other variables.

After casting, the "H" section was cut into two "tees" for tests as a cantilever beam or as tensile and bend specimens cut from the tee. Figure 6 shows the casting and its chill areas. This casting configuration will be referred to hereafter as the tee bar. A second objective of this configuration was to develop a cut specimen for inspection use that would have the same statistical order, when tested, as the order of the tee bar or other type of structure.

The aluminum alloy castings were given two types

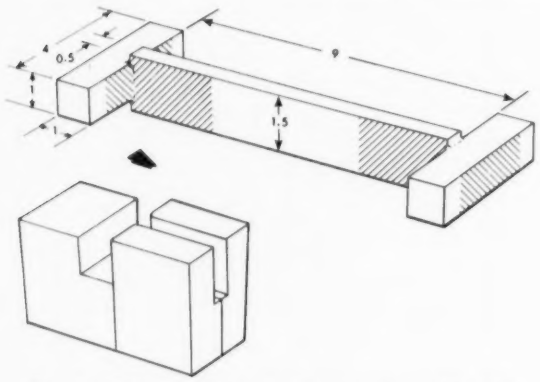


Fig. 6 — Tee bar casting for bend testing, with chill areas shown.

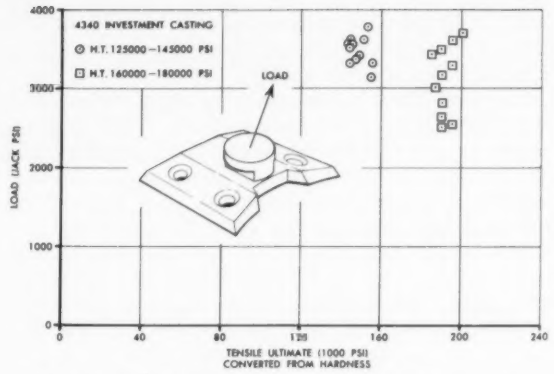


Fig. 5 — 4340 investment cast steel at two heat treating levels.

of aging treatment to determine its effect on bending strength. The longer aging time improved the performance of the chill cast material, and in some cases lowered the performance of the sand cast material. A second purpose of the two types of aging treatments was to provide a greater range in elongation to determine if there is a minimum value of elongation for structural use.

Figure 7 shows the cantilever bending test results for both sand cast and chill cast tee bars of several aluminum and magnesium alloys. These castings were all produced as special test parts under carefully controlled foundry conditions, and were free of radiographic defects at the critical bending area. Therefore, the results represent the best that can be expected from the alloys, and are above the typical values for an average production casting. Figure 8 shows the average value for each alloy and heat treatment.

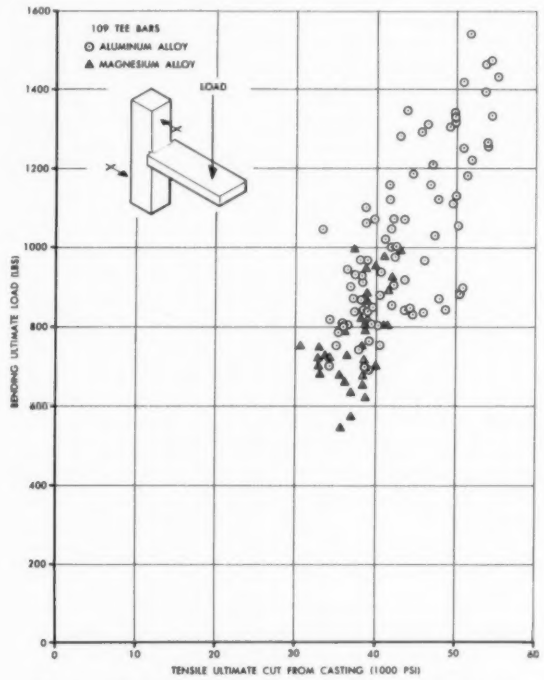


Fig. 7 — Tee bar cantilever beam test vs. cut tensile tests for sand cast and chill cast specimens.

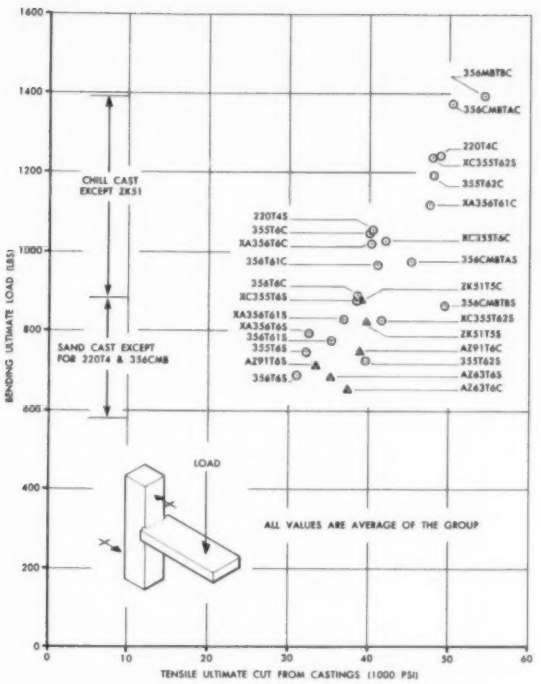


Fig. 8 — Average of tee bar bend vs. tensile tests for each alloy and heat treatment.

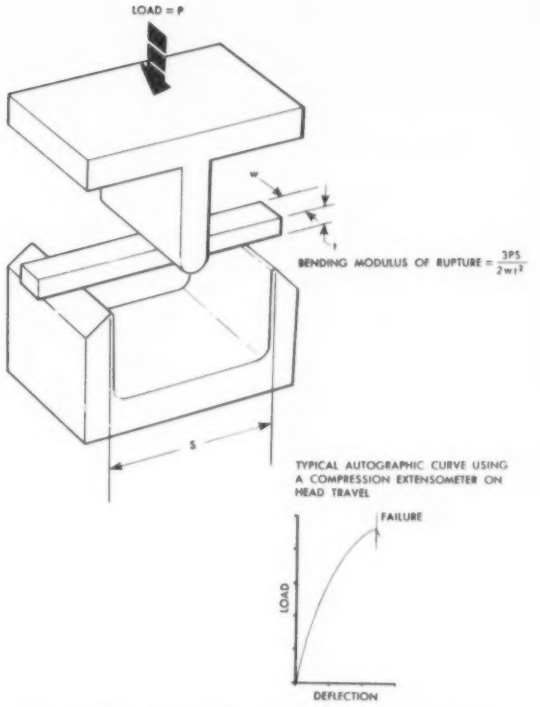


Fig. 9 — Bend test method for cut bars, showing a typical curve and the equation for computing the bending modulus of rupture stress.

The large range (two to one) of load for a given tensile stress, as shown in Fig. 7, indicates that tensile values are not reliable as an inspection method for bending performance of a material.

In order to obtain a better evaluation of bending behavior, the author's company began testing small bend specimens machined from castings. An arbitrary size was selected that could be cut from the same area of a casting from which tensile specimens were already being taken. The bending bar was ¼-in. thick and ⅜-in. wide, and was loaded as a simple beam with a 2-in. span. The ¼-in. thickness was thought to be deep enough to minimize the effect of small casting defects, and the machining was simple because of the constant cross-section without notches. Figure 9 shows the loading method, a typical curve and the equation for computing the bending modulus of rupture stress. (The appendix gives an explanation of the modulus of rupture effect.)

Figure 10 shows the plot of the tee bar vs. the ¼-in. x ⅜-in. bend bar cut from the same casting. The same large range is still present, as shown in Figure 7. The materials tested included some that were intentionally heat treated to a brittle condition, such as sand cast 355T62. This brittle condition may explain some of the low side scatter of Fig. 10.

Tables 2 and 3 compare the tee bar bend tests, tensile tests and small bend specimen tests (all values are the average value for a group of tee bars). The bend tests are shown as modulus of rupture stress and the "K" values $\frac{\text{(modulus of rupture)}}{\text{(tensile ultimate)}}$ are also shown.

Figure 11 shows average value and autographic load vs. beam deflection curves for both the tee bars and the small bend bars. The shapes of the curves are similar, which indicates that the shape characteristic will prove to be the best inspection method for ductile behavior in bending structures. A particular

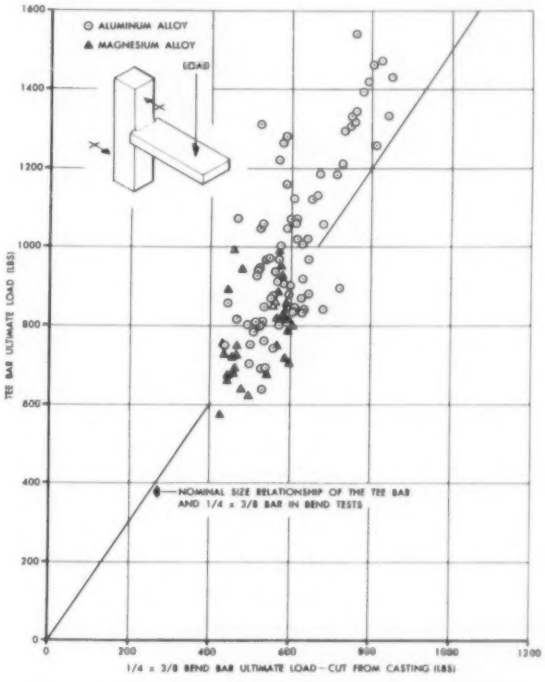

ALUMINUM ALLOY
MAGNESIUM ALLOY
LOAD
TEE BAR ULTIMATE LOAD (LBS)
NOMINAL SIZE RELATIONSHIP OF THE TEE BAR AND 1/4 x 3/8 BAR IN BEND TESTS
1/4 x 3/8 BEND BAR ULTIMATE LOAD - CUT FROM CASTING (LBS)

Fig. 10 — Tee bar cantilever test vs. cut bending bars taken from the same casting.

shape of the curve parameter may be selected as a criterion, and small bend specimens may be used for inspection as tensile tests are used today.

This technique was used for an investment casting in 410 alloy stainless steel as a measure of its ductile behavior. Figure 12 shows typical curves obtained from production lot samples. The geometry of the casting limited the size of the bend specimen to a ¼-in. x ¼-in. cross-section loaded on a 1-in. span. The specimen size and span have some effect on the shape of the curve, but any consistant geometry of the specimen may be used on a lot to lot comparison basis.

TABLE 2 — SUMMARY OF TEE BAR TESTS (SAND CAST)

Alloy and H.T.	Tensile, Ultimate	Tensile, Yield	% Elong.	Tee Bar MR	Tee Bar K	¼x⅜x2 Bar MR	¼x⅜x2 Bar K
355T6	32200	27200	1.4	71400	2.2		
XC355T6	38500	33800	1.7	83900	2.2	70000	1.8
355T62	39600	—	—	69300	1.8	67300	1.7
XC355T62	41700	—	0.9	79400	1.9	70400	1.7
356T6	31000	25400	2.5	66100	2.1		
XA356T6	32500	27000	3.0	76000	2.3	61900	1.9
356T61	35200	29900	2.2	74500	2.1	64000	1.8
XA356T61	36800	32800	2.3	79600	2.2	69000	1.9
356CMBTA	45200	37000	5.1	87800	1.9	79400	1.8
356CMBTB	49500	45300	2.4	83000	1.7	84400	1.7
220T4	40300	27900	8.1	101100	2.5		
AZ63T6	35200	19800	3.2	65900	1.9	56500	1.6
AZ91T6	33300	23100	3.0	68600	2.0	57900	1.7
ZK51T5	39400	23400	9.1	79300	2.0	70600	1.8

TABLE 3 — SUMMARY OF TEE BAR TESTS (CHILL CAST)

Alloy and H.T.	Tensile, Ultimate	Tensile, Yield	% Elong.	Tee Bar MR	Tee Bar K	¼x⅜x2 Bar MR	¼x⅜x2 Bar K
355T6	40300	28800	5.3	100800	2.5	69500	1.7
XC355T6	42000	32600	5.7	98600	2.4	82400	2.0
355T62	48000	42700	2.8	114400	2.4	87000	1.8
XC355T62	48200	42200	2.2	118700	2.5		
356T6	38500	29800	4.4	85300	2.2	68500	1.8
XA356T6	40200	28300	10.2	97700	2.4	75800	1.9
356T61	41000	32400	3.8	92700	2.3	75000	1.8
XA356T61	47400	38200	4.0	107403	2.3	85300	1.8
356CMBTA	50300	37400	13.3	137400	2.7	96500	1.9
356CMBTB	54200	45200	8.4	133300	2.5	103300	1.9
220T4	47800	25700	12.3	119300	2.5	76300	1.6
AZ63T6	37400	21000	3.6	62600	1.7	64200	1.7
AZ91T6	38900	22200	4.6	71800	1.8	74600	1.9
ZK51T5	38700	24700	8.4	83700	2.2	73100	1.9

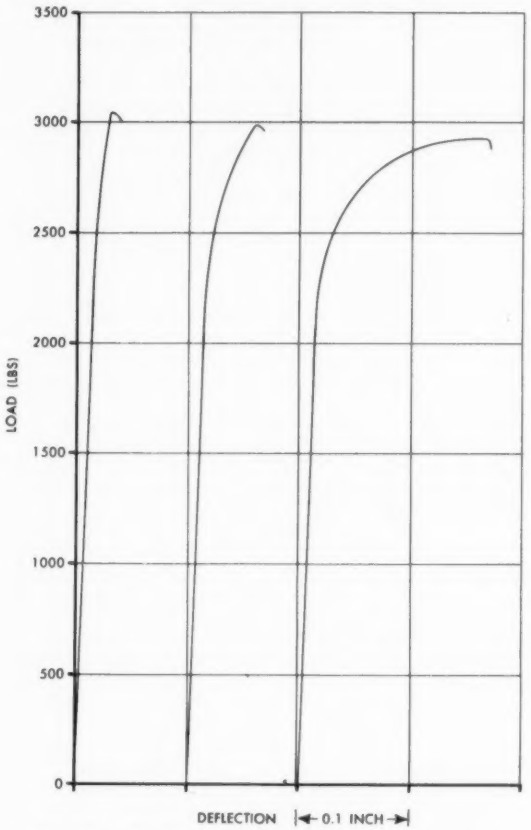


Fig. 12 — Bend tests of 410 stainless steel investment casting obtained from production lot samples.

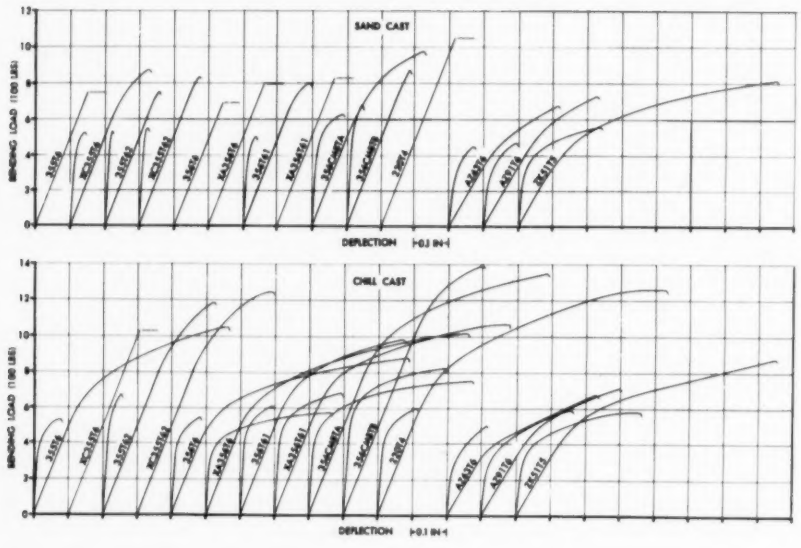


Fig. 11 — Typical curves of tee bars and cut bending bars showing average value and autographic load vs. beam deflection curves.

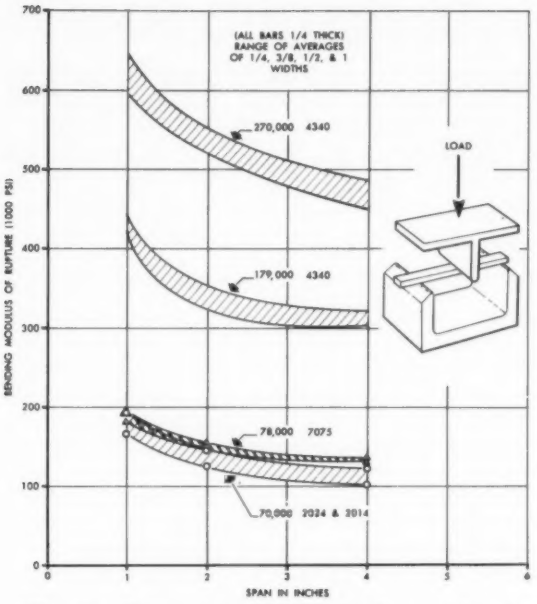


Fig. 13 — Bar geometry effect on bending modulus of rupture.

GEOMETRY EFFECT ON BEND SPECIMENS

A study was made of the geometry effect on bend specimens in wrought material. All specimens of a group were machined from the same piece of plate stock in an effort to minimize the effect of material variations. A constant thickness of ¼-in. was selected and widths of ¼, ⅜, ½ and 1 in. were tested over spans of 1, 2 and 4 in.

The width proved to have only a minor effect on the modulus of rupture over the range that was tested. Figure 13 shows the effect of span on the constant depth beams. Further work is needed to determine the mechanism of this variation before the high modulus values can be used for other than comparative testing. Figure 14 shows the effect of beam width on the shape of load vs. deflection curve, and must be taken into account on curve shape criteria.

A study of the shape of the various load deflection curves indicates that an acceptable level of that vague quality ductility may be defined as a parameter of the curve shape. This parameter may need to be different for various types of structural service.

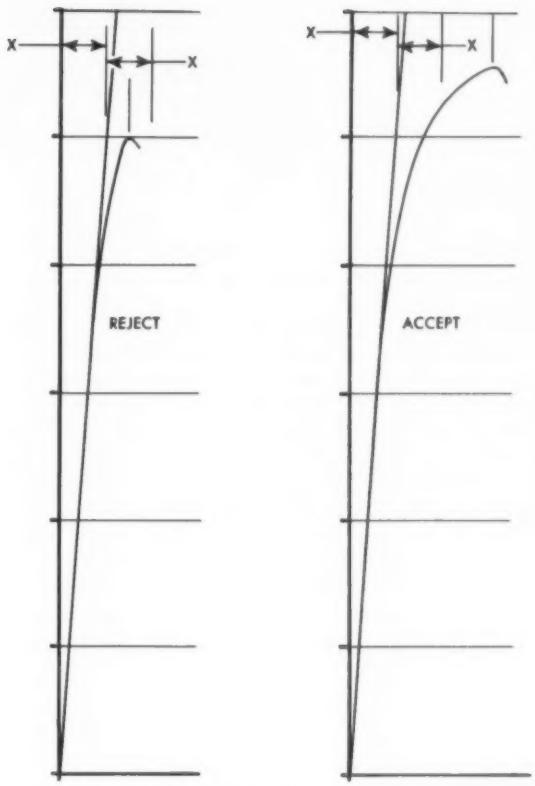


Fig. 15 — Shape parameter for load—deflection curves.

We are really looking for some property "X" that demonstrates the ability of a material to redistribute a load around a notch in the load path. Therefore, the curve parameter may need to differ with the degree of notch in the structure. The writer offers, as a minimum acceptable degree of ductility, the following curve parameter:

> The total deflection offset, at the failure point, must be equal to or greater than, twice the offset of the elastic line when it is projected to the failure or ultimate load. Figure 15 shows a diagram of this shape of the curve parameter.

CONCLUSIONS

The results presented are a preliminary appraisal

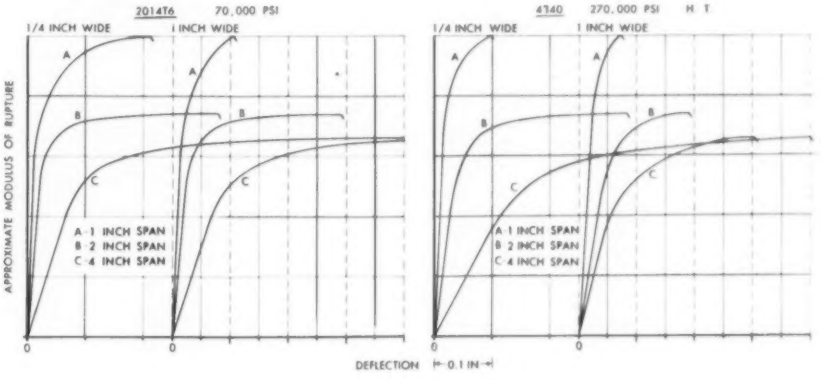


Fig. 14 — Bar width effect on stress—deflection curves.

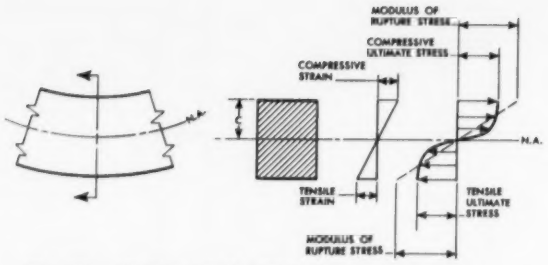


Fig. 16 — Various relationships shown on a beam.

of bend testing, and much more work should be done to complete the evaluation. The bending test specimen appears to be a useful tool for evaluating the ductile behavior of metals. It is hoped that other laboratories and test facilities will investigate bending specimens along with their normal tensile testing. A proved correlation between bend specimens and static tests of cast structures will build much greater confidence in the structural job that good castings can perform. Future specifications for high strength cast materials should include a demonstrated modulus of rupture stress as well as tensile stress. A guaranteed modulus of rupture stress will enable the designer to use cast structures in more critical applications and have more efficient configurations.

APPENDIX

The conventional beam formula $F_b = \frac{MC}{I}$ is true for stresses in the elastic range of the stress-strain curve of the structural material. When the beam stress is above the proportional limit and into the plastic range of the stress-strain curve, a correction factor called modulus of rupture is used. The $\frac{MC}{I}$ formula gives a stress that is proportional to the distance c from the neutral axis of the beam to its surface or extreme fiber. Beam experiments have shown that, in a ductile material, the extreme fibers will yield and allow the fibers underneath the surface to pick up more than their proportional share of the load.

Therefore, modulus of rupture is a correction factor applied to the elastic beam formula to make it usable for beams stressed into the plastic range of the material. It is given as an allowable factor of increase over the tensile stress of the material (usually called K) or, as an equivalent fictitious tensile stress. Figure 16 shows these relationships on a beam.

STARCH CONTENT EFFECT ON A RAMMED GRAPHITIC MOLD MATERIAL FOR CASTING TITANIUM

By H. W. Antes and R. E. Edelman

ABSTRACT

The starch content effect on the properties of the rammable graphitic mold material was determined. Specimens were made by molding at pressures of 30, 60 and 120 psi for graphitic mixtures containing 4, 6, 8 and 10 per cent starch by weight. It was found that the best combinations of properties were obtained with mixtures containing 6 to 8 per cent starch. A mixture containing 6 per cent starch and molded at 120 psi provided molds which were equivalent to machined graphite molds with respect to minimizing surface contamination of resulting titanium castings.

It has been found that sometimes it is necessary to use starch contents higher than 6 per cent to facilitate the removal of complex shaped patterns without damaging the mold. In this case, the starch content may be increased but it should not be in excess of 8 per cent, since maximum strengths are obtained with an 8 per cent starch mix. Maximum density and thermal conductivity also are observed with an 8 per cent starch mix. In addition, it has been found that mold shrinkage is directly proportional to starch content and inversely proportional to molding pressure. The mold surface finish is good and is not sensitive to starch content for the range studied.

INTRODUCTION

The development of the rammable graphitic mold material has facilitated the production of shaped castings of titanium and other high melting point reactive metals.[1,2,3] Common foundry molding techniques have been used with the graphitic material to make complex molds and cores. After the material is molded it is air dried, baked and finally fired to produce an entirely graphitic and carbonaceous mold.

The constituents used in preparing the graphitic material are powdered graphite, carbonaceous cement, starch, powdered pitch, a surface activating agent and water. The proportion of these constituents as originally proposed produced a paste-like product.[1,2] In order to refine the material into a consistency more desirable for molding an investigation on the effect of moisture content was conducted.[3] It was found that by properly mulling the material it was necessary to use only ¼ to ⅓ the amount of water that was proposed originally.

In addition, it was found that molding pressure was an important variable. As a result of the investigation the optimum moisture content and minimum molding pressure were found to be 6 per cent and 100 psi, respectively. It was found, by using this moisture content and molding pressure, rammed graphitic molds could be made which closely approached the performance of machined graphite molds with respect to minimizing the surface contamination of cast titanium.

It was felt that the chemical inertness as well as other properties of the rammable graphitic material could be improved further by determining the optimum content of the other constituents. Starch appeared to be the most important of the remaining constituents, since shrinkage, density, thermal conductivity, as well as strength should be sensitive to the starch content. Therefore, starch content was selected for study in this investigation.

MATERIALS

Electric furnace graphite powder was used as the basic material. The sieve analysis of this material is given in Table 1.

The AFS grain fineness number for this material was approximately 85. The other constituents were instant laundry starch (finely powdered), carbonaceous cement, pulverized pitch, a surface activating agent and tap water.

The standard mix shown in Table 2 was used to prepare the specimens. Various amounts of starch were added to this mixture to give 4, 6, 8 and 10 per cent starch by weight.

PROCEDURE AND METHODS

The preparation of the test specimens and the methods used for determining the properties of the gra-

TABLE 1 — SIEVE ANALYSIS OF ELECTRIC FURNACE GRAPHITE

U.S. No.	Retained, Per Cent	Cumulative Per Cent	Size (Microns)
60	26.5	26.5	246
70	10.8	37.3	210
80	16.0	53.3	175
100	12.3	65.6	147
120	9.7	75.3	125
140	5.8	81.1	104
PAN	18.9	100.0	

H. W. ANTES is Met., and R. E. EDELMAN is Chief, Reactive Metals Unit, Research and Development Group, Frankford Arsenal, Philadelphia.

TABLE 2 — MOLD MATERIAL COMPOSITION USED FOR SPECIMEN PREPARATION

Component	Part by Weight
Graphite Powder AFS No. 85	61.0
Pitch	11.5
Carbonaceous Cement	9.0
Water	6.0
Surface Activating Agent	1.0

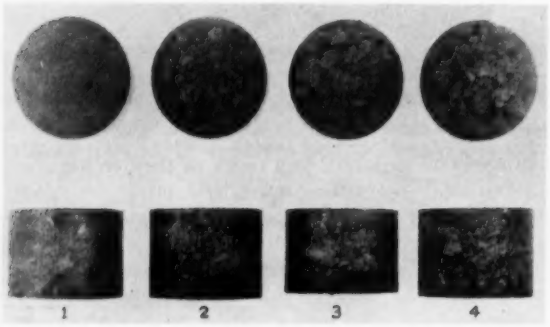


Fig. 1 — Surface standards by rating numbers for graphitic mold material.

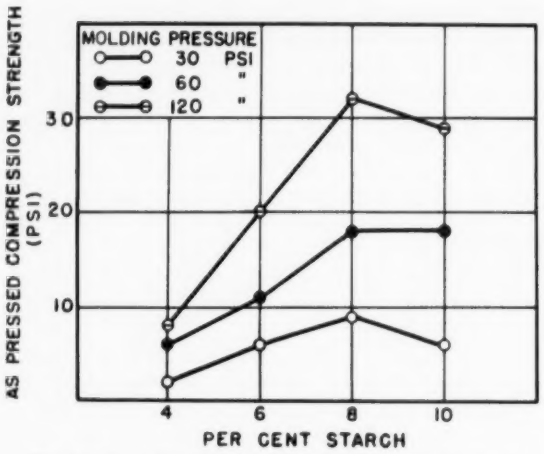


Fig. 2 — As-pressed compression strength vs. per cent starch for graphitic mold material.

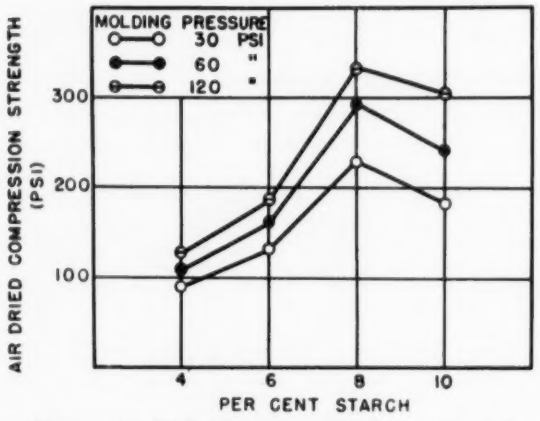


Fig. 3 — Air dried compression strength vs. per cent starch for graphitic mold material.

phitic material have been presented in detail in a previous report.[3]

The starch contents used were 4, 6, 8 and 10 per cent by weight. The molding pressures that were employed for each of the starch contents were 30, 60 and 120 psi.

The properties that were determined for each of the 12 combinations of starch content and molding pressure are listed below:

1) Surface finish.
2) Compression strength.
3) Density.
4) Permeability.
5) Thermal conductivity.
6) Shrinkage.
7) Surface contamination of resulting titanium castings.

TEST RESULTS

Surface Evaluation

An arbitrary set of standards for evaluating the surface finish of the molded specimens after firing had been established in a previous investigation. These standards, reproduced in Fig. 1, represent a gradient from the smoothest to the roughest surfaces that were obtained when the moisture content was varied from 4 to 10 per cent with molding pressures from 30 to 120 psi.

In the current investigation smooth surfaces (ratings of 1 or slightly more than 1) were obtained for all starch contents and molding pressures. This indicates that good surface finish can be obtained consistently as long as the water content is kept at a low level.

Compression Strength

The compression strengths vs. per cent starch, immediately after molding (as pressed), after air drying for 4 days (air dried), after baking at 250 F for 6 hr (baked) and after firing in a reducing atmosphere to 2000 F (fired), are shown in Figs. 2, 3, 4 and 5, respectively. In these figures it can be seen that a maximum is obtained with each molding pressure for the material containing 8 per cent starch.

In addition, by comparing these figures it can be seen that appreciable increases in strength are observed in going from one step of the process to the next, and that the strength is sensitive to both mold-

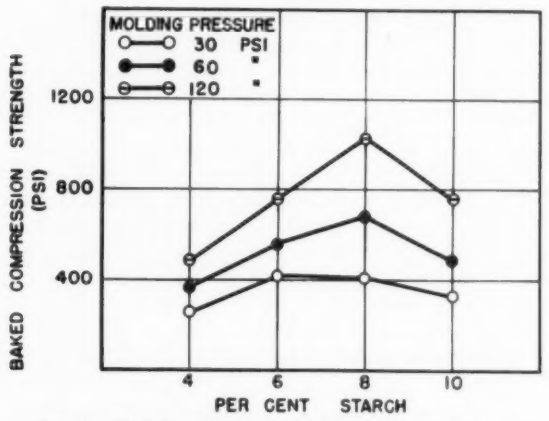


Fig. 4 — Baked compression strength vs. per cent starch for graphitic mold material.

TABLE 3 — COMPRESSION STRENGTH OF GRAPHITIC SPECIMENS

Starch, %	Stress (psi)* at Molding Pressure (psi) 30	60	120
As Pressed			
4	2	6	8
6	6	11	20
8	9	18	32
10	6	18	19
Dried			
4	90	110	129
6	136	162	186
8	227	292	334
10	183	240	305
Baked			
4	254	366	490
6	420	560	760
8	410	680	1030
10	333	492	760
Fired			
4	698	896	1010
6	820	1166	1455
8	1095	1650	1840
10	792	1166	1550

* Average of three tests

ing pressure and starch content. The actual compression strength data are listed in Table 3.

Density

The density of the various specimens was calculated, after firing, from weight and volume measurement. The effects of starch content and molding pressure on the density are shown in Fig. 6. In this figure it can be seen that as the starch content is increased from 4 per cent the density increases slightly. At approximately 8 per cent starch the density reaches a maximum. As the starch content is increased to 10 per cent a decrease from the maximum is observed.

From these curves it can be concluded that molding pressure has a greater effect on the density than has starch content. Higher molding pressures produce higher densities. The variation in density for the various specimens ranged from 0.93 to 1.08 g/cm^3, as compared to a density of approximately 1.75 g/cm^3 for machined graphite. These data are listed in Table 4.

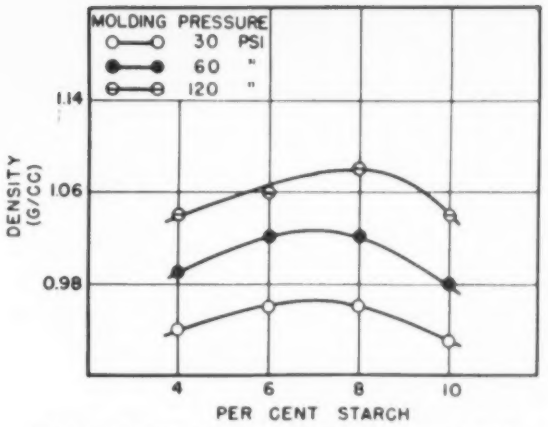


Fig. 6 — Density vs. per cent starch for graphitic mold material.

Permeability

The permeability vs. per cent starch is plotted in Fig. 7 for the three molding pressures employed. This figure shows that as the starch content is increased from 4 per cent the permeability decreases to a minimum at 8 per cent and then increases. The initial decrease is substantially linear for the two higher molding pressures. Actually, the change in permeability (82 to 89) with starch content is slight for specimens molded at the lowest pressure. The range of permeability that was observed for the molding pressures and starch contents was approximately 30 to 90. The

TABLE 4 — DENSITY OF FIRED GRAPHITIC SPECIMENS

Starch, %	Density (g/cm^3) at Molding Pressure (psi) 30	60	120
4	0.94	0.99	1.04
6	0.96	1.02	1.06
8	0.96	1.02	1.08
10	0.93	0.98	1.04

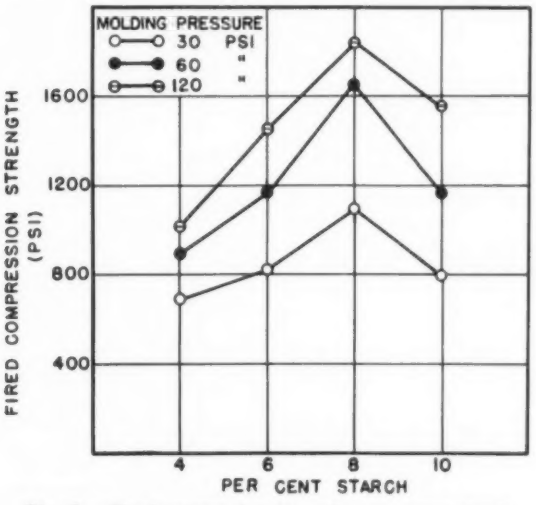


Fig. 5 — Fired compression strength vs. per cent starch for graphitic mold material.

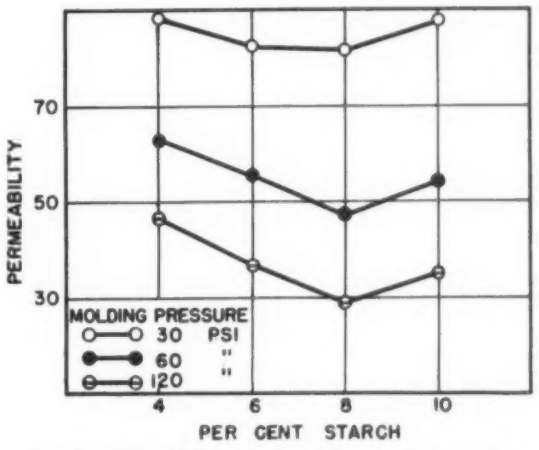


Fig. 7 — Permeability vs. per cent starch for graphitic mold material.

TABLE 5 — PERMEABILITY OF FIRED GRAPHITIC SPECIMENS

Starch, %	Permeability Number* at Molding Pressure (psi) 30	60	120
4	88.6	63.2	46.2
6	82.3	55.4	36.8
8	81.5	47.3	29.0
10	87.7	54.0	35.1

* Average of duplicate tests on each of two specimens

permeability of machined graphite for all practical purposes is zero. The permeability data are listed in Table 5.

Thermal Conductivity

The thermal conductivity vs. per cent starch is plotted in Fig. 8. These curves illustrate the point that the highest conductivities are obtained at the highest molding pressure for each starch content, and that for the three molding pressures a maximum conductivity is observed in the 6 to 8 per cent starch range. These data are relative values and are used to express trends only.[3] The thermal conductivity data, which were calculated from a value of 80 (Btu/hr/ft/degree F) for machined graphite, are given in Table 6.

Shrinkage

The average mold shrinkage as a function of the starch content is plotted for the three molding pressures in Fig. 9. These shrinkage data are the change in linear dimensions from the as-pressed to the fired condition. Figure 9 shows that the shrinkage increases as the starch content increases, and decreases as the molding pressure increases. The actual shrinkage values for the various starch contents and molding pressures are given in Table 7.

TABLE 6 — THERMAL CONDUCTIVITY OF GRAPHITIC SPECIMENS

Starch, %	Thermal Conductivity (Btu/hr ft° F) at Molding Pressure (psi) 30	60	120
4	15.1	19.5	19.5
6	19.4	22.3	23.4
8	19.8	21.6	24.7
10	17.6	19.9	22.7

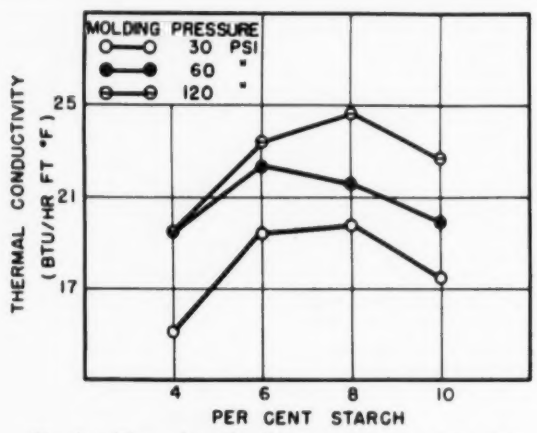


Fig. 8 — Thermal conductivity vs. per cent starch for graphitic mold material.

Surface Contamination

The most important property of a mold material for casting titanium or other reactive metals is its chemical inertness in the presence of the molten metal. The standard procedure for determining this property is a Knoop microhardness traverse taken on the resulting casting. The microhardness traverses for the castings made with the 4, 6, 8 and 10 per cent starch content molds are shown in Figs. 10, 11, 12 and 13, respectively. In these figures the curve for the machined graphite mold has been corrected to the same base hardness as that of the rammable graphitic molds.

This was necessary because the data for the machined graphite molds were obtained from castings of titanium which had a slightly higher base hardness than that observed in this investigation.[3] It can be seen from these curves that the performance of the rammable mold material compares favorably with the machined graphite molds. The best results were obtained with the 6 and 8 per cent starch molds.

In Fig. 11 it can be seen that the curves for the 6 per cent starch—120 psi molding pressure and the machined graphite mold are almost coincident. The base hardness of the titanium used in this investigation is approximately 120 Bhn. All of the microhardness data are listed in Table 8.

DISCUSSION

The results of this investigation illustrate that expendable molds with smooth surfaces can be obtained with a graphitic material containing 4 to 10 per cent starch, when molding pressures of 30 to 120 psi are

TABLE 7 — SHRINKAGE OF GRAPHITIC SPECIMENS

Starch, %	Shrinkage (in./ft) at Molding Pressure (psi) 30	60	120
4	0.24	0.22	0.16
6	0.25	0.23	0.20
8	0.31	0.26	0.22
10	0.34	0.29	0.25

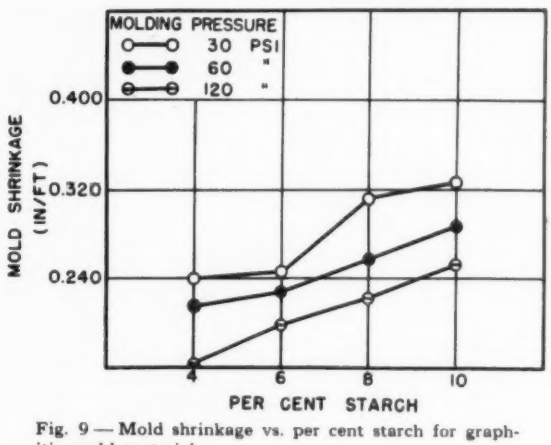


Fig. 9 — Mold shrinkage vs. per cent starch for graphitic mold material.

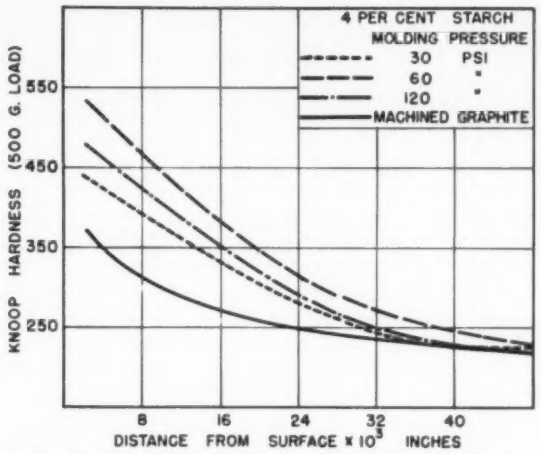


Fig. 10 — Knoop hardness vs. distance into metal from mold-metal surface, 4 per cent starch material.

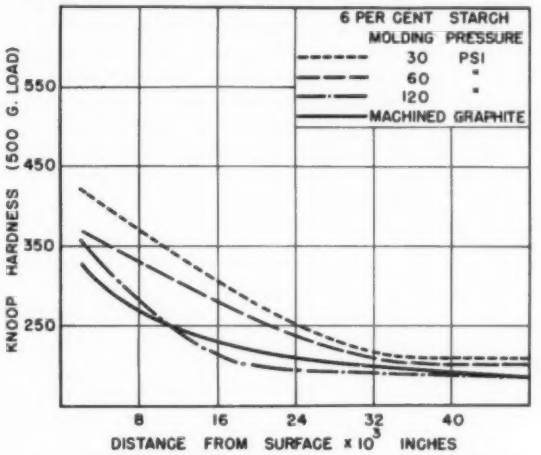


Fig. 11 — Knoop hardness vs. distance into metal from mold-metal surface, 6 per cent starch material.

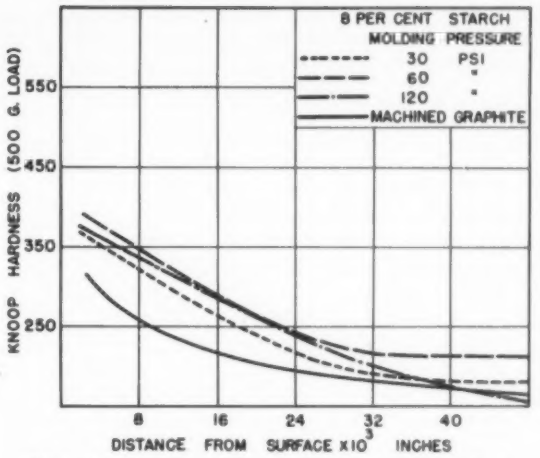


Fig. 12 — Knoop hardness vs. distance into metal from mold-metal surface, 8 per cent starch material.

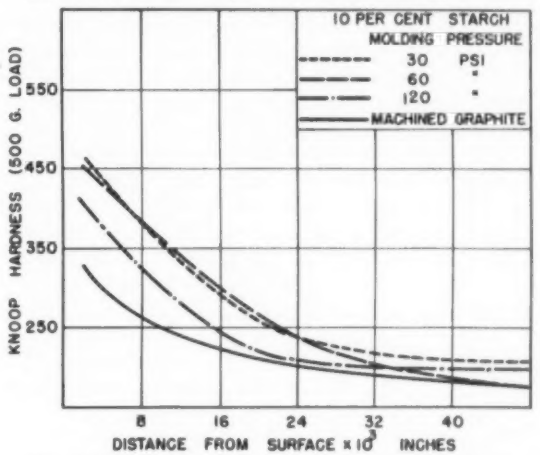


Fig. 13 — Knoop hardness vs. distance into metal from mold-metal surface, 10 per cent starch material.

TABLE 8 — KNOOP HARDNESS (500-g LOAD) VS. DISTANCE FROM MOLD-METAL INTERFACE FOR GRAPHITIC SPECIMENS OF VARIOUS STARCH CONTENTS AND MOLDING PRESSURES

Distance from Interface (in.)	Knoop Hardness* (500g Load)											
	4 Per Cent Starch and Molding Pressure (psi)			6 Per Cent Starch and Molding Pressure (psi)			8 Per Cent Starch and Molding Pressure (psi)			10 Per Cent Starch and Molding Pressure (psi)		
	30	60	120	30	60	120	30	60	120	30	60	120
0.002	—	—	—	358	315	224	322	353	275	472	462	355
0.004	410	411	469	405	344	337	333	335	333	428	425	355
0.006	420	494	430	378	339	305	346	346	337	386	386	358
0.008	380	465	390	381	351	285	351	367	339	360	318	326
0.010	386	438	428	353	329	260	301	358	337	341	381	315
0.012	346	465	476	339	313	236	271	335	339	344	322	271
0.014	350	408	438	320	322	226	297	299	320	326	370	253
0.018	344	396	311	313	277	218	270	271	285	330	353	226
0.022	307	415	303	307	261	222	240	255	238	253	344	233
0.026	317	341	293	289	242	226	244	248	231	256	270	214
0.030	320	287	261	279	207	200	230	219	236	281	247	240
0.034	234	261	263	233	196	197	182	233	199	251	202	211
0.038	227	258	279	208	200	160	173	204	175	218	193	192
0.042	228	283	221	211	184	177	174	215	172	210	184	203
0.046	228	255	216	208	208	170	203	229	160	209	175	205
0.250	228	210	218	214	210	175	160	220	160	196	203	211
0.254	—	—	215	218	201	192	176	217	150	205	218	212

*Average of two tests

Note: Hardness data for machined graphite is the average of three readings taken from reference 3.

employed. The strength of the mold is sensitive to both starch content and molding pressure. Maximum strength is obtained with an 8 per cent starch mix for all of the molding pressures studied in this investigation.

Higher molding pressures produce higher strength for each of the starch contents. Maximum density and thermal conductivity were observed for the material that contained from 6 to 8 per cent starch. The permeability was minimum for an 8 per cent starch mix at each of the molding pressures.

The important properties of a mold material for use in the casting of titanium are 1) surface, 2) thermal conductivity, 3) permeability and 4) inertness. A smooth surface is necessary for good reproduction of the pattern. High thermal conductivity is desirable because the metal will be cooled rapidly, and thus minimize the reaction of the cast metal with the mold material. However, the conductivity can be too high for the amount of super-heat in the metal, and produce rippled surfaces on the resulting castings. Rippled surfaces have been observed on titanium castings made in machined graphite molds.

Greater super-heat can eliminate rippled surfaces; however, because of the nature of the arc-melting process, large power inputs are needed to obtain this additional super-heat. An alternate method that may be used to eliminate ripples is to use a mold material with a thermal conductivity less than machined graphite. The rammable graphitic molds with 6 to 8 per cent starch have conductivities that vary from approximately ¼ to ⅓ of the conductivity of machined graphite.

Apparently, these conductivities are sufficiently high to prevent serious contamination, and yet low enough to eliminate the rippled surface on the castings without excessive super-heating. Since the conductivity of the rammable material is lower than machined graphite or copper, it is entirely feasible to incorporate chills of these materials in the mold to encourage directional solidification.

The main reason for controlling permeability in the mold material is to prevent penetration into the interstices of the mold by the molten metal. In a previous investigation this phenomenon was observed at the edges of molds with higher permeabilities.[3] In the current investigation, however, no edge penetration was observed. This was due first to the finer graphite that was used, and second to the reduced starch content.

Any material that contains constituents which volatilize on firing usually suffers shrinkage. Since the rammable graphitic material does contain an appreciable amount of volatiles, the problem of shrinkage is especially important. The amount of distortion and possible cracking brought about by shrinkage can be excessive in molds where the section size varies. It is therefore necessary that the shrinkage be held to an absolute minimum. In addition to being small, the shrinkage should be consistent to facilitate accurate pattern design.

The shrinkage of the rammable mold material decreases as the starch content is decreased and the molding pressure is increased. The shrinkage was found to vary from 0.16 to 0.34 in./ft for the starch contents and molding pressures used in this investigation. The 6 per cent starch mix when molded at 120 psi shrinks 0.198 in./ft.

The most important property of a mold material for use in casting titanium is its inertness (determined by microhardness traversal of the resulting castings). In this investigation, the minimum surface contamination was observed for a 6 per cent starch mix molded at 120 psi. The inertness of these molds was similar to that of machined graphite molds.

The results of this investigation indicate that the most desirable molds for casting titanium should be made from a mix containing 6 per cent starch and molded at a minimum pressure of 120 psi. However, it has been found from experience at the Frankford Arsenal that when complex shapes are molded it is difficult to draw the pattern without damaging the mold if the 6 per cent starch mix is used. Therefore, higher starch contents up to but not exceeding 8 per cent are recommended for molding complex shapes. The increase in starch content increases the as pressed strength of the mold and facilitates pattern removal without damage to the mold.

CONCLUSIONS

1) The optimum combination of properties of the rammable graphitic mold material is obtained with a mixture containing 6 to 8 per cent starch and molded with a minimum pressure of 120 psi.
2) A mixture of this material containing 6 per cent starch and molded at 120 psi provides molds which are equivalent to machined graphite molds with respect to minimizing depth and degree of surface contamination of resulting titanium castings.
3) The molding of complex shapes requires starch contents higher than 6 per cent, in order to facilitate pattern removal. Starch contents up to but not exceeding 8 per cent may be used to minimize pattern removal difficulties.
4) Maximum compression strength, density and thermal conductivity are obtained with molds made from an 8 per cent starch mix.
5) Shrinkage of rammed graphite molds is directly proportional to starch content and inversely proportional to molding pressure.
6) Mold surface finish is good and insensitive to starch content in the range of 4 to 10 per cent starch.

REFERENCES

1. Feild, A. L., Jr., "Expendable Molds for Titanium Castings," *Metal Progress, vol. 70, No. 4*, pp. 92-96, Oct. 1956.
2. Feild, A. L., Jr., and Edelman, R. E., "The Use of Expendable Graphite Molds in the Production of Sound Ductile Titanium Castings," AFS Transactions, *vol. 65*, p. 517, 1957.
3. Antes, H. W., Norton, J. T., and Edelman, R. E., "Foundry Characteristics of a Rammed Graphitic Mold Material for Casting Titanium," AFS Transactions, *vol. 66*, p. 135, 1958.

DUCTILITY AND STRENGTH OF HIGH-CARBON GRAY IRONS

By E. M. Stein and H. O. McIntire

ABSTRACT

Composition, microstructure and inoculation effects on ductility and strengtfi of high-carbon (3.5-4.5 per cent) cast irons were evaluated. Irons melted by cupola, induction and blast furnace were included in the study. Some of the cupola and induction-melted irons were inoculated with ferrosilicon or with proprietary inoculating agents.

The criterion of ductility was the total elongation (or total strain) reached before fracture. Strain was measured with SR-4 gages cemented to standard tensile specimens. Ductility decreased with increasing manganese contents above 0.5 per cent. Inoculation of low-manganese (0.3-0.5 per cent) irons produced up to 50 per cent increase in elongation, but the effect of inoculation decreased with increasing manganese content. Ductility was not affected significantly by a wide variation in silicon content and the associated variation in microstructure.

For induction-melted and cupola irons, a relatively close relationship was found between carbon equivalent and strength, but the strength of the blast-furnace irons was considerably higher than this relationship would suggest. Increasing the Mn content above 0.5 per cent markedly increased the tensile strength through the associated increase of pearlite. Tensile strength was not affected by inoculation beyond the normal decrease from the increased silicon. There was a reasonably close correlation between hardness and strength for all of the irons.

INTRODUCTION

Many investigations dealing with properties of gray irons have been reported. Most of this work has involved gray irons with less than 3.5 per cent total carbon. This is understandable, because the bulk of the gray iron tonnage falls below this carbon level. However, higher carbon irons are desirable for many applications, the most notable being for heat resistance.

It was the purpose of this study to determine some of the factors (composition, inoculation and microstructure) that affect ductility and strength of irons having carbon contents from 3.5 to about 4.5 per cent.

Gray irons have so little ductility that this property often is ignored, but in applications where failure by cracking is encountered even a small increase in ductility can be important. For this reason, SR-4 strain gages were used in this study for obtaining accurate measurement of elongation.

E. M. STEIN is Principal Met. Eng. and H. O. McINTIRE is Asst. Chief, Met. Eng. Div., Battelle Memorial Institute, Columbus, Ohio.

The study included 36 heats made by induction melting, 28 separate casts of cupola iron and 4 casts of blast-furnace iron.

PROCEDURE

Melting, Casting, and Sampling

Thirty-five heats of high-carbon cast iron, and one heat of a low-carbon iron, were melted in a basic-lined, high-frequency induction furnace. The charge for each high-carbon heat consisted of 83 lb of a low-phosphorus pig iron and 15 lb low-carbon steel. For the low-carbon heat, the ratio of pig iron to steel was reduced. Additions to obtain the desired composition were made at melt-down, using ferrosilicon, ferromanganese, ferrophosphorus and iron pyrites. When When the temperature reached 2700 F, the heats were tapped into a ladle and poured at 2550-2600 F. The same procedure was followed for the inoculated heats, except that the inoculants were added and stirred when the metal temperature in the ladle had dropped to 2600 F. Three inoculants were used in this investigation. One of these, designated "A", was the 75 per cent grade of ferrosilicon. Inoculants "B" and "C" are proprietary alloys, and their compositions are given in Table 1.

Y-blocks 3 in. thick were cast from each heat in open-top dry sand molds. Figure 1 shows the Y-block dimensions, which were the same as 3 in. A.S.T.M.[1] nodular iron Y-blocks, except for the over-all height, and the height of the test section proper. These dimensions were 7½ and 4½ in. as compared with 5⅝ and 2⅝ in. respectively, for the A.S.T.M. blocks. Immediately after filling the molds, they were covered with dry sand, and the castings were allowed to cool in the molds overnight. Y-blocks of the same dimensions were cast with cupola and blast-furnace iron, and these also were cooled in the molds overnight.

Duplicate tensile specimens were cut from symmetrical locations at the bottom of the Y-blocks, according to the drawing in Fig. 2, which also shows the dimensions of the tensile specimens. These were standard A.S.T.M. Type B specimens, but with a somewhat longer reduced section than is customarily used. This longer section provided adequate space for installation of strain gages and connection of the wires.

Brinell hardnesses were obtained for each set of duplicate bars prior to machining. The hardness impressions were located approximately 1 in. from an as-cast surface.

Mechanical Testing

The method for measuring strain was similar to that used by Flinn and Chapin.[2] Two SR-4 strain gages (Type A-1) were cemented 180 degrees apart on each bar. These gages were connected in series, and were balanced by two temperature-compensating gages, also connected in series. An SR-4 strain indicator was used to measure strains during loading, which was performed at a constant crosshead speed of 0.005 in. per min. The strain was followed to the point of fracture, with readings taken at load increments of 1000 lb. The strain immediately preceding fracture is referred to in this paper as elongation* and is the total elongation, which consists of plastic plus elastic strain. After fracture, one bar from each duplicate set was sectioned at the gage length and examined metallographically.

*Elongation and ductility are used interchangeably.

RESULTS

The data obtained in this study are listed in Tables 1 and 2, the former dealing with induction-melted irons, and the latter with cupola and blast-furnace irons. The induction-melted irons are grouped according to the chemical or inoculation variables. For example, Heats 2-6 were nominally of the same composition except for silicon contents. In several instances in Table 1 the same heat is listed more than once, if it fits into a progressive change in one of the

TABLE 1 — PROPERTIES OF INDUCTION-MELTED IRONS

Heat No.	Major Variable	% T.C.	% Si	% Mn	% P	% S	% Si Added as inoculant*	Tensile Strength, 1000 psi First Bar	Tensile Strength, 1000 psi Second Bar	Tensile Strength, 1000 psi Ave.	Elongation, % First Bar	Elongation, % Second Bar	Elongation, % Ave.	Bhn, 3000 kg	% Ferrite in Matrix	Carbon Equivalent, T.C.+1/3 (Si+P)
1	Low carbon	3.00	1.96	0.54	0.14	0.04	—	29.0	28.6	28.8	0.77	0.86	0.82	165	10	3.70
2	Silicon	3.53	1.07	0.52	0.11	0.04	—	26.2	25.8	26.0	1.15	0.10	1.12	159	Trace	3.93
3		3.74	1.56	0.53	0.13	0.03	—	17.7	17.0	17.3	0.94	1.21	1.08	126	25	4.30
4		3.67	1.96	0.51	0.14	0.03	—	10.6	10.6	10.6	0.93	0.90	0.92	101	45	4.37
5		3.74	2.02	0.55	0.13	0.03	—	8.7	8.4	8.5	1.01	0.83	0.92	105	65	4.45
6		3.57	2.44	0.55	0.13	0.03	—	8.9	9.0	9.0	0.66	1.23	0.94	86	85	4.42
7	Silicon	3.74	1.11	0.31	0.13	0.03	—	19.6	19.9	19.8	0.87	1.04	0.95	154	10	4.15
8		3.67	1.43	0.31	0.13	0.03	—	20.3	21.1	20.7	0.88	0.90	0.89	155	20	4.19
9	Silicon	3.68	1.29	0.62	0.14	0.08	—	20.1	20.0	20.1	0.91	0.88	0.90	137	10	4.16
10		3.72	1.84	0.64	0.14	0.09	—	13.0	12.7	12.8	0.88	0.91	0.90	109	30	4.38
3	Manganese	3.74	1.56	0.53	0.13	0.03	—	17.7	17.0	17.3	0.94	1.21	1.08	126	25	4.30
11		3.64	1.51	0.77	0.13	0.03	—	22.2	22.1	22.1	0.95	0.92	0.93	146	Trace	4.18
12		3.68	1.58	1.08	0.13	0.03	—	20.9	21.0	21.0	0.77	0.70	0.74	146	0	4.25
13		3.92	1.51	1.34	0.13	0.03	—	18.0	17.2	17.6	0.78	0.60	0.69	140	0	4.46
14	Phosphorus	3.69	1.61	0.79	0.04	0.03	—	17.4	18.3	17.9	0.78	0.82	0.80	128	10	4.24
11		3.64	1.51	0.77	0.13	0.03	—	22.2	22.1	22.1	0.95	0.92	0.93	146	Trace	4.18
15		3.70	1.58	0.80	0.19	0.03	—	20.8	20.8	20.8	0.89	0.82	0.85	143	5	4.29
11	Sulfur	3.64	1.51	0.77	0.13	0.03	—	22.2	22.1	22.1	0.95	0.92	0.93	146	Trace	4.18
16		3.74	1.55	0.80	0.13	0.08	—	19.7	19.6	19.7	0.91	0.90	0.91	143	Trace	4.30
17		3.72	1.59	0.78	0.13	0.13	—	16.8	16.8	16.8	0.85	0.85	0.85	126	10	4.29
18	Kind of	3.69	1.47	0.51	0.13	0.03	0.20 A	18.1	18.0	18.1	1.30	1.29	1.30	126	15	4.22
19	inoculant	3.55	1.45	0.50	0.13	0.03	0.20 B	21.0	21.2	21.1	1.33	1.32	1.32	126	15	4.07
20		3.73	1.52	0.52	0.13	0.03	0.20 C	15.8	15.6	15.7	1.44	1.33	1.38	111	35	4.28
7	Inoculation	3.74	1.11	0.31	0.13	0.03	—	19.6	19.9	19.8	0.87	1.04	0.95	154	10	4.15
21		3.73	1.10	0.32	0.13	0.03	0.20 C	20.8	20.8	20.8	1.37	1.42	1.39	137	20	4.14
8		3.67	1.43	0.31	0.13	0.03	—	20.3	21.1	20.7	0.88	0.90	0.89	155	20	4.19
22		3.73	1.38	0.32	0.13	0.03	0.20 C	17.6	17.5	17.6	1.39	1.29	1.34	126	30	4.23
2	Amount of	3.53	1.07	0.52	0.11	0.04	—	26.2	25.8	26.0	1.15	1.10	1.12	159	Trace	3.93
23	inoculant	3.72	1.06	0.51	0.13	0.03	0.05 C	20.8	21.0	20.9	1.30	1.28	1.29	143	10	4.11
24		3.72	0.98	0.55	0.13	0.03	0.10 C	21.8	21.8	21.8	1.03	0.96	0.99	143	5	4.09
25		3.65	0.94	0.53	0.13	0.03	0.20 C	24.5	24.6	24.6	1.09	1.11	1.10	163	5	4.00
26		3.71	1.03	0.53	0.13	0.03	0.40 C	23.4	22.8	23.1	1.47	1.33	1.40	156	5	4.09
27	Amount of	3.78	1.29	0.51	0.13	0.03	0.05 C	18.0	17.9	18.0	1.15	1.13	1.14	131	20	4.25
28	inoculant	3.68	1.41	0.52	0.13	0.03	0.10 C	18.6	18.4	18.5	1.14	1.20	1.17	136	20	4.19
29		3.71	1.27	0.52	0.13	0.03	0.20 C	20.6	20.4	20.5	1.24	1.22	1.23	142	20	4.17
30		3.72	1.35	0.50	0.13	0.03	0.40 C	17.8	17.8	17.8	1.39	1.30	1.35	136	30	4.21
11	Amount of	3.64	1.51	0.77	0.13	0.03	—	22.2	22.1	22.1	0.95	0.92	0.93	146	Trace	4.18
31	inoculant	3.61	1.50	0.77	0.13	0.03	0.05 C	22.2	22.1	22.2	0.98	1.00	0.99	156	5	4.15
32		3.65	1.50	0.77	0.13	0.03	0.10 C	21.2	21.4	21.3	1.06	1.05	1.05	143	5	4.19
33		3.71	1.46	0.76	0.13	0.03	0.20 C	18.6	18.6	18.6	1.07	1.07	1.07	143	10	4.24
34		3.67	1.47	0.79	0.13	0.03	0.40 C	20.8	20.8	20.8	1.14	1.08	1.11	143	10	4.20
35	Sulfur	3.73	1.46	0.67	0.12	0.02	0.20 C	16.3	16.7	16.5	0.88	1.13	1.01	131	20	4.26
36		3.76	1.43	0.68	0.14	0.08	0.20 C	17.4	17.4	17.4	1.10	1.08	1.09	140	25	4.29

*A—Ferrosilicon containing 75 per cent silicon.
B—Proprietary alloy containing 45-50 per cent Si, 9-11 per cent Ti, and 5-8 per cent Cr.
C—Proprietary alloy containing 60-65 per cent Si, 5-7 per cent Mn, and 5-7 per cent Zr.

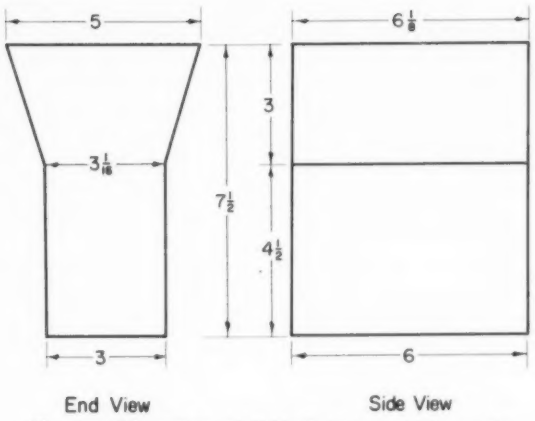


Fig. 1 — Dimensions of Y-block in in., which are the same as 3 in. A.S.T.M. nodular iron Y-blocks, except for the over-all height and height of test section proper.

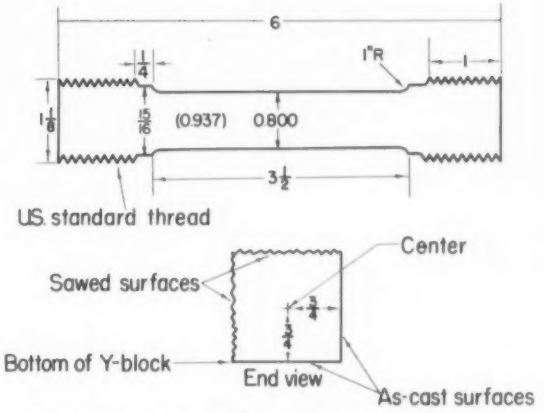


Fig. 2 — Location and dimension in in. of tensile bars cut from symmetrical locations at the bottom of the Y-blocks.

elements or a change in type or amount of inoculant. Table 2 lists the uninoculated and inoculated cupola irons and blast-furnace irons, each group being listed according to increasing carbon equivalent.

Composition and Inoculation Effects on Ductility

Of the variables evaluated, only manganese content and inoculation appeared to have important effects on ductility. The effects of manganese level and of inoculation are illustrated for induction-melted irons in Fig. 3. As the manganese content was increased above 0.5 per cent, there was a tendency for the elongation values to decrease. This was true for both inoculated and uninoculated irons. Particularly at manganese levels of 0.5 per cent or less, inoculation markedly increased the elongation. In the irons containing approximately 0.8 per cent manganese and over minute particles of massive cementite were detected, and it is believed that these particles may account for the decrease in elongation. Figure 4 shows one of these cementite particles, and it will be noted that two of its branches extend along pearlite grain boundaries. A hard, brittle constituent such as this would be expected to reduce ductility.

All of the cupola irons had relatively high manganese contents, ranging from 0.64 per cent to 1.00 per cent. Also, there are only seven inoculated irons available for comparison. Nevertheless, by grouping the irons into two ranges of manganese contents with and without inoculation in Table 3, the effects of these variables become apparent. The results indicate that decreasing the manganese content from an average of about 0.88 per cent to 0.75 per cent increased the elongation from about 0.93 to 1.04 per cent. Also, the inoculated irons had slightly higher elongations than the uninoculated irons. Considering the results obtained for induction-melted iron, it seems likely that ductility of the cupola irons would have been higher at lower manganese levels and that the effect of inoculation would have been more pronounced.

The effect of the amount of inoculant on ductility is illustrated for induction-melted irons in Fig. 5. For manganese levels of about 0.5 and 0.8 per cent, increasing the amount of inoculant (in this instance in-

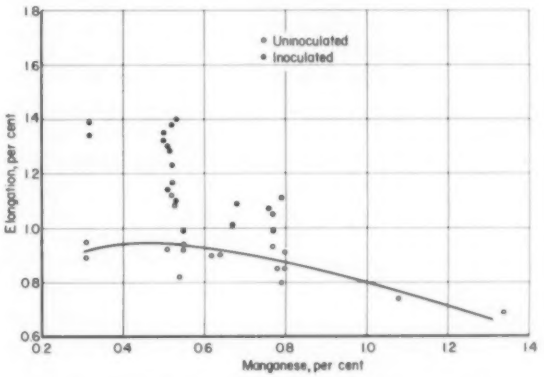


Fig. 3 — Manganese and inoculation effects on elongation for induction-melted irons.

Fig. 4 — Particle of massive cementite in pearlitic matrix from heat 11 (0.77 per cent Mn). Picral etch. 500 ×.

oculant C) resulted in progressive increases in ductility. Figure 5 also shows that the effect of inoculation was more pronounced for the iron containing 0.3 per cent manganese than for irons of higher manganese contents.

Elongation of the blast-furnace irons tended to be quite erratic, with individual values of 0.47-1.22 per cent. The coarseness of the graphite flakes probably is responsible for this erratic behavior, since a few large flakes oriented in an unfavorable direction (normal to the direction of principal stress), particularly at the surface of the specimen, could lower the capacity for deformation.

The silicon content was varied from 1.07 per cent in heat 2, to 2.44 per cent in heat 6. With other compositional factors remaining essentially constant, the increased percentages of silicon resulted in increased amounts of ferrite, reaching 85 per cent with 2.44 per cent silicon. Although ferrite by itself is the most ductile of the micro-constituents, increasing the percentage of ferrite through increased silicon did not result in increased ductility. Instead, the high-silicon, high-ferrite irons tended to have less ductility than the lower silicon irons.

Little can be said of the effect of phosphorus and sulfur contents on elongation. The ranges covered were rather narrow (0.04-0.19 per cent of phosphorus, and 0.02-0.09 per cent of sulfur), but within these limits no noticeable effect on elongation was observed.

TABLE 3 — MANGANESE CONTENT AND INOCULATION EFFECTS ON CUPOLA IRONS ELONGATION

No. of	Manganese Range, %				Elongation, %		
Tests	Min.	Max.	Ave.	Inoculation	Min.	Max.	Ave.
11	0.64	0.80	0.75	no	0.83	1.22	1.04
3	0.77	0.80	0.78	yes	1.04	1.14	1.09
9	0.81	1.00	0.88	no	0.82	1.00	0.93
4	0.81	0.89	0.84	yes	0.76	1.09	1.01

Composition and Microstructure Effects on Tensile Strength

The relationship between carbon equivalent, having the customary formula of Total Carbon + 1/3 (Si + P), and tensile strength for the three groups of irons, is shown in Fig. 6. A reasonably narrow band encompasses all but four of the induction-melted and cupola irons, and includes even the low-carbon iron

TABLE 2 — PROPERTIES OF CUPOLA AND BLAST-FURNACE IRONS

Heat	%					% Si Added as	Tensile Strength, 1000 psi			Elongation, %			Bhn, 3000	% Ferrite in	Carbon Equivalent,
No.	T.C.	Si	Mn	P	S	Inoculant*	First Bar	Second Bar	Ave.	First Bar	Second Bar	Ave.	kg	Matrix	T.C.+1/3(Si+P)
Cupola Irons															
37	3.63	1.62	0.75	0.12	0.04	—	18.2	18.8	18.5	1.00	1.16	1.08	128	10	4.21
38	3.64	1.63	0.70	0.13	0.03	—	19.6	19.5	19.5	1.04	1.20	1.12	128	10	4.22
39	3.74	1.33	0.73	0.13	0.04	—	18.8	18.8	18.8	1.06	1.02	1.04	130	Trace	4.22
40	3.63	1.75	0.77	0.14	0.03	—	18.2	18.8	18.5	0.83	0.83	0.83	127	Trace	4.26
41	3.66	1.67	0.78	0.12	0.03	—	16.9	17.2	17.1	1.12	1.21	1.17	130	10	4.26
42	3.71	1.62	0.64	0.13	0.03	—	16.1	15.8	16.0	1.11	1.00	1.06	120	20	4.29
43	3.71	1.79	0.79	0.14	0.04	—	16.3	16.8	16.6	0.99	0.97	0.98	132	10	4.36
44	3.77	1.65	0.93	0.14	0.02	—	16.6	16.2	16.4	0.94	0.81	0.87	131	5	4.37
45	3.82	1.53	0.83	0.14	0.02	—	15.3	15.0	15.1	0.90	1.06	0.98	130	10	4.38
46	3.79	1.62	0.76	0.17	0.03	—	16.8	16.6	16.7	0.91	0.94	0.92	131	5	4.39
47	3.90	1.41	0.82	0.15	0.03	—	11.6	11.6	11.6	0.98	1.00	0.99	126	5	4.42
48	3.87	1.53	0.92	0.14	0.02	—	11.8	11.7	11.8	0.95	0.96	0.95	120	10	4.43
49	3.86	1.60	0.90	0.17	0.03	—	12.3	12.4	12.3	1.00	1.00	1.00	107	10	4.45
50	3.84	1.77	1.00	0.14	0.02	—	12.4	12.4	12.4	0.95	0.90	0.93	121	10	4.48
51	3.68	1.61	0.81	0.13	0.04	—	17.0	17.0	17.0	1.08	0.89	0.99	136	10	4.26
52	3.68	1.82	0.81	0.13	0.04	0.20 A	15.6	14.9	15.2	1.19	1.01	1.10	121	15	4.33
53	3.70	1.78	0.77	0.14	0.04	—	16.4	16.4	16.4	1.00	0.99	0.99	121	15	4.34
54	3.70	1.91	0.77	0.14	0.04	0.20 C	13.7	13.5	13.6	1.16	1.12	1.14	108	25	4.39
55	3.72	1.76	0.77	0.13	0.04	—	15.4	14.9	15.1	1.12	1.05	1.08	116	20	4.35
56	3.72	1.96	0.77	0.13	0.04	0.20 A	12.0	12.0	12.0	1.09	1.07	1.08	109	30	4.41
57	3.78	1.64	0.80	0.14	0.04	—	15.4	14.8	15.1	1.20	1.24	1.22	120	15	4.38
58	3.70	1.86	0.80	0.13	0.04	0.20 C	12.5	12.1	12.3	1.07	1.01	1.04	106	25	4.36
59	3.75	1.79	0.89	0.13	0.04	—	12.8	12.6	12.7	0.92	0.86	0.89	111	15	4.39
60	3.75	1.89	0.89	0.13	0.04	0.20 C	11.7	11.6	11.7	1.05	1.14	1.09	110	20	4.42
61	3.79	1.78	0.80	0.13	0.02	—	12.2	12.0	12.1	1.02	1.10	1.06	111	20	4.42
62	3.77	1.93	0.82	0.13	0.02	0.20 C	10.2	9.8	10.0	1.04	1.13	1.08	108	30	4.45
63	3.80	1.94	0.84	0.14	0.04	—	13.1	12.6	12.8	0.83	0.81	0.82	116	30	4.50
64	3.80	2.03	0.84	0.14	0.04	0.20 C	10.1	10.5	10.3	0.54	0.97	0.76	109	35	4.53
Blast-Furnace Irons															
65	4.39	1.82	1.22	0.13	0.03	—	9.6	10.5	10.0	0.68	0.88	0.78	104	30	5.04
66	4.47	1.65	1.07	0.16	0.02	—	9.2	10.4	9.8	0.94	0.72	0.83	117	15	5.07
67	4.32	2.28	1.20	0.14	0.02	—	11.4	11.6	11.5	1.22	0.82	1.02	101	50	5.13
68	4.44	2.19	1.25	0.14	0.02	—	9.2	9.6	9.4	0.47	0.62	0.54	96	40	5.22

*A—Ferrosilicon, containing 75 per cent silicon.
C—Proprietary alloy, containing 60-65 per cent Si, 5-7 per cent Mn, and 5-7 per cent Zr.

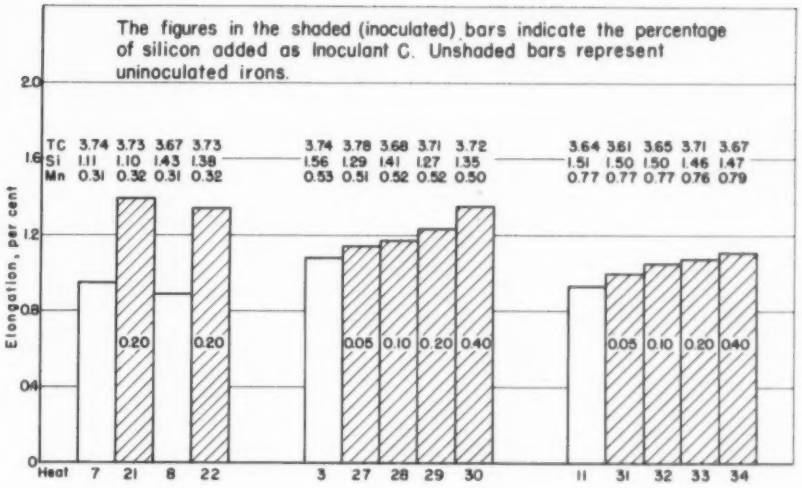


Fig. 5 — Inoculation effect on elongation of induction-melted irons at three manganese levels (0.3, 0.5 and 0.8 per cent). Increasing the amount of inoculant resulted in progressive increases in ductility.

with a carbon equivalent of 3.70. This relationship coincides closely with that shown by Schneidewind and McElwee[3] for 4-in. thick sections.

In Fig. 6, the points for the blast-furnace irons are displaced considerably from those representing induction-melted and cupola irons. The carbon equivalents for the four blast-furnace irons were extremely high (5.04-5.22), yet the tensile strengths obtained for them were at a level that was obtained with cupola and induction-melted irons having carbon equivalents of about 4.5. It is suggested, as a possible explanation, that despite the greater amount of graphitic carbon in the blast-furnace irons, they had larger graphite-free areas than the cupola or induction-melted irons of similar strength.

Figures 7-10 show typical microstructures of low-strength irons melted by the three different methods. The largest circles that can be inscribed in graphite-free areas in the induction-melted and cupola irons (Figs. 7 and 8, respectively), are much smaller than those that can be inscribed in graphite-free areas in the blast-furnace irons (Figs. 9 and 10). Furthermore, because of some thick graphite flakes in the blast-furnace irons, it is likely that the remainder actually possessed a lower carbon equivalent than the induction-melted and cupola irons of Figs. 7 and 8.

With essentially constant carbon content and a manganese level of approximately 0.5 per cent, the tensile strength was drastically reduced when the silicon content was increased from 1.07 in heat 2 to 2.02 per cent in heat 5. The tensile strength decreased from 26,000 psi for the 1.07 per cent silicon iron, to 8500 psi for the iron of 2.02 per cent silicon content. These changes in silicon content and tensile strength were accompanied by an increase in free ferrite, from a trace in the lower silicon iron to 65 per cent in the higher silicon iron. A further increase in the silicon content to 2.44 per cent (heat 6), increased the amount of ferrite to 85 per cent, but the tensile strength increased slightly to 9000 psi. This slight in-

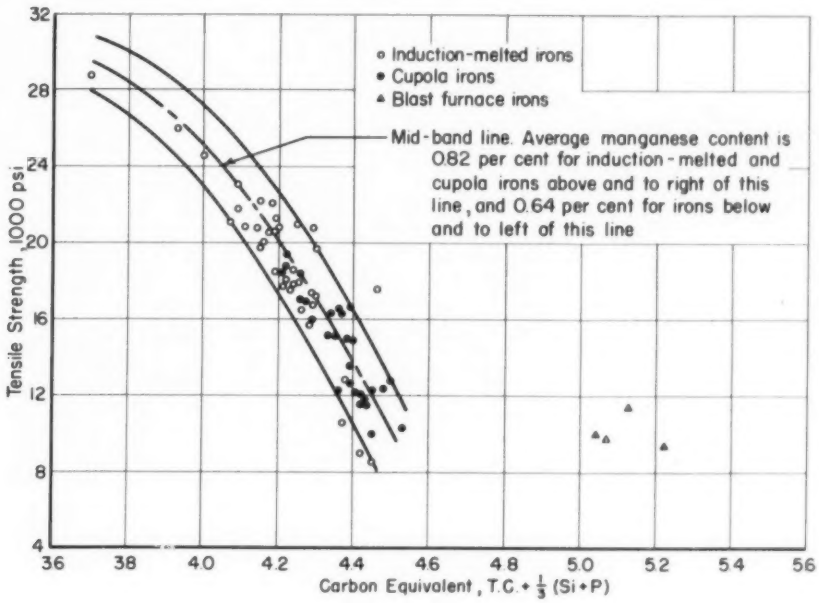

o Induction-melted irons
• Cupola irons
▲ Blast furnace irons
Mid-band line. Average manganese content is 0.82 per cent for induction-melted and cupola irons above and to right of this line, and 0.64 per cent for irons below and to left of this line
Tensile Strength, 1000 psi
Carbon Equivalent, T.C. + 1/3 (Si + P)

Fig. 6 — The relationship between carbon equivalent and tensile strength for the three groups of irons.

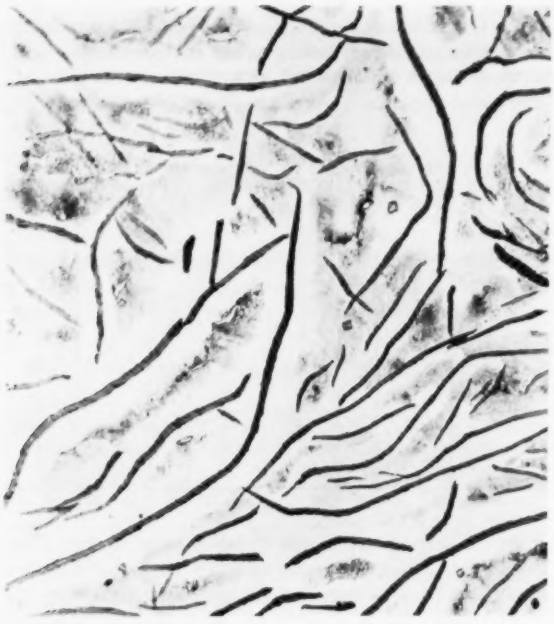


Fig. 7 — Typical microstructure of low-strength induction-melted iron, from heat 5. Tensile strength—8400 psi, carbon equivalent—4.45. Picral etch. 100 ×.

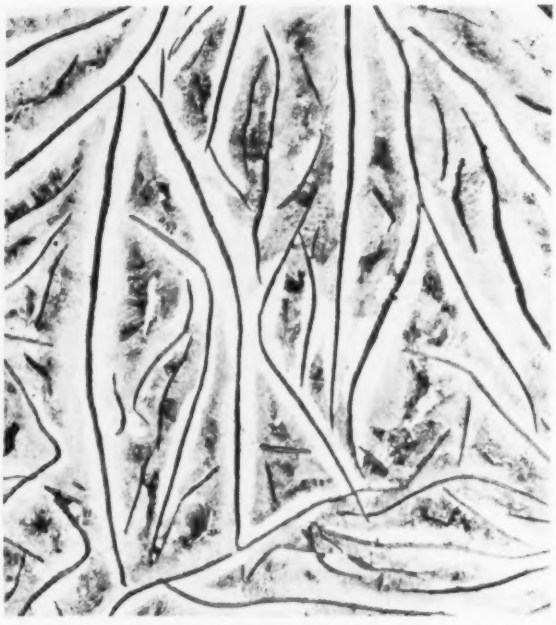


Fig. 8 — Typical microstructure for low-strength cupola iron, from heat 62. Tensile strength—10,200 psi; carbon equivalent—4.45. Picral etch. 100 ×.

crease in strength above that for the 2.02 per cent silicon iron is explained by the decrease in carbon equivalent as the result of a lower carbon content.

An indication of the effect of manganese content on tensile strength can be obtained by comparing heats 3, 11 and 12, all of which had similar total carbon (3.7 per cent) and silicon (1.55 per cent) contents. The tensile strengths were 17,300 psi for the iron having 0.53 per cent manganese, and 22,100 psi for the iron of 0.77 per cent manganese content. This substantial increase in strength resulted mainly from the reduction in the amount of free ferrite, the former having 25 per cent ferrite as compared with only traces of ferrite in the latter.

Heat 12 with 1.08 per cent manganese had a tensile strength of 21,100 psi. This indicates that addition of

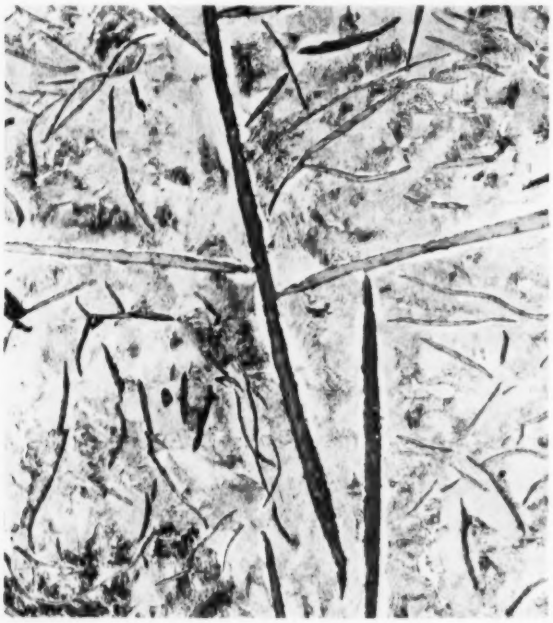


Fig. 9 — Heat 66
Carbon equivalent — 5.07
Tensile strength — 10,400 psi

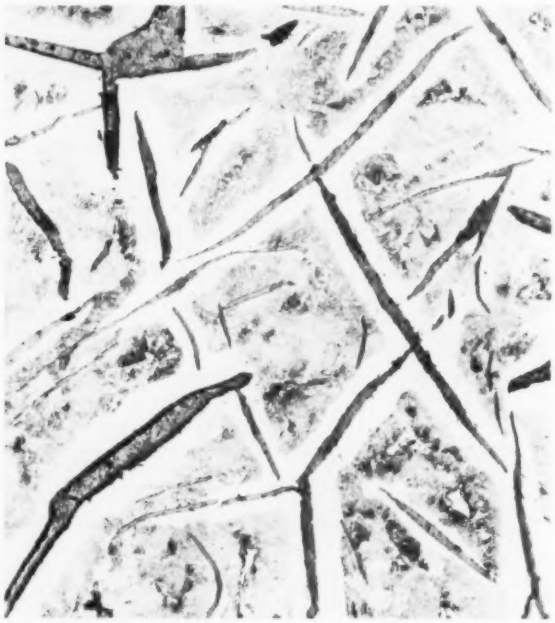


Fig. 10 — Heat 67
Carbon equivalent — 5.13
Tensile strength — 11,400 psi

Figs. 9-10 — Typical microstructure of blast-furnace irons. Picral etch. 100 ×.

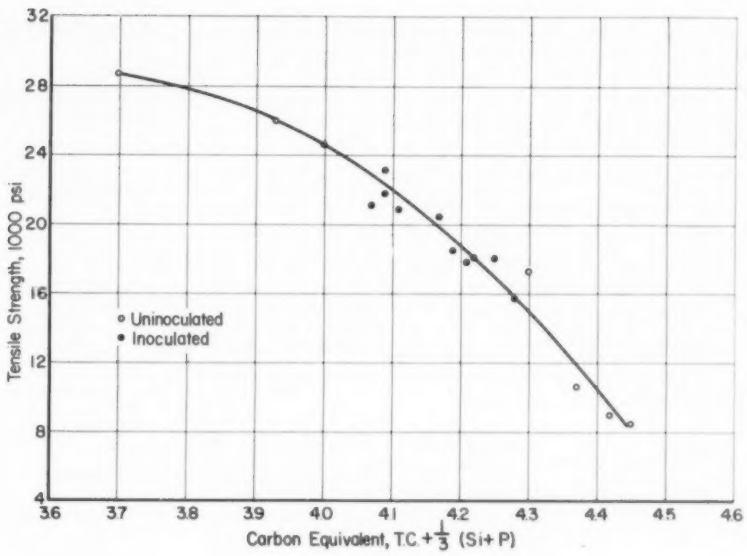


Fig. 11 — Graph showing the carbon equivalent-tensile strength relationship for all induction-melted irons containing 0.50-0.55 per cent manganese.

manganese beyond that required to give a fully pearlitic matrix does not result in increased strength. Heat 13 contained 1.34 per cent manganese, but it cannot be included conveniently in the comparison because it also had a relatively high carbon equivalent which would tend to offset the strengthening effect of the higher manganese. The effect of manganese in strengthening the iron also is apparent in Fig. 6. The irons above and to the right of the middle of the band averaged 0.82 per cent manganese. Those below and to the left of the middle of the band averaged 0.64 per cent manganese.

Figure 11 reveals that inoculation had no effect on tensile strength except through the normal effect of increased silicon. The data plotted in Fig. 11 represent induction-melted irons only, but the same was true for the cupola irons. This observation is in agreement with the conclusion reached by Burgess and Bishop[4] that, as the carbon equivalent approaches 4.0, ladle inoculation does not materially affect the tensile strength. In lower-carbon irons that tend to have dendritic arrangement of the graphite flakes, inoculation generally serves to reduce this dendritic tendency. However, the graphite in these higher carbon irons was essentially of random arrangement (Type A) without inoculation.

A straight-line relationship was found between hardness and tensile strength for the induction-melted, cupola, and blast-furnace irons, regardless of composition or treatment. A plot of hardness and tensile strength for the irons investigated is shown in Fig. 12. Approximately 95 per cent of the points were within a range of about ± 3000 psi from the mean. Only 3 points fell outside of this range, one point for each of the induction-melted, cupola, and blast-furnace irons. It is especially interesting to note that three of the four blast-furnace irons correlated well with the other irons in this respect.

Results of this study permit the following conclu-

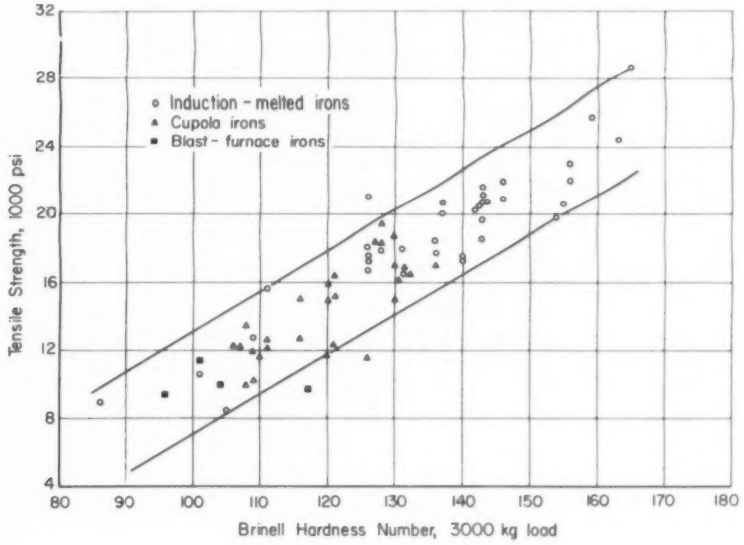

Tensile Strength, 1000 psi
Brinell Hardness Number, 3000 kg load
o Induction - melted irons
▲ Cupola irons
■ Blast - furnace irons

Fig. 12 — Graph showing Brinell hardness and tensile strength relationship for the irons investigated.

sions regarding high-carbon gray irons of low phosphorus and sulfur contents and for a particular cooling rate.

CONCLUSIONS

1) Ductility is influenced significantly by the manganese content; manganese levels greater than about 0.5 per cent appear to reduce ductility.

2) Increasing the percentage of free ferrite in the matrix by increasing the carbon or silicon contents does not increase ductility.

3) Ductility may be increased significantly by inoculation provided the manganese content does not exceed about 0.6 per cent.

4) Carbon and silicon contents are the principal compositional factors affecting tensile strength. Increasing the carbon equivalent, per cent TC + ⅓ (Si + P), from about 4.0 to about 4.5 decreases the tensile strength of induction-melted and cupola irons from about 25,000 psi to 10,000 psi.

5) Manganese additions result in higher strengths so long as they produce increased proportions of pearlite in the matrix.

6) Inoculation has no significant influence on the tensile strength except through the normal effect of the increased silicon content.

ACKNOWLEDGMENT

The authors wish to thank Vulcan Mold and Iron Co. for their sponsorship of this investigation, for their cooperation in obtaining the cupola blocks and for permission to publish the results.

REFERENCES

1. A.S.T.M. Designation: A339-55. Standard Specifications for Nodular Iron Castings.
2. R. A. Flinn, and H. J. Chapin, "Ductility and Elasticity of White and Gray Irons", AFS Transactions, *vol. 54*, pp. 141-153 (1946).
3. R. Schneidewind, and R. G. McElwee, "Composition and Properties of Gray Iron", Part I, AFS Transactions, *vol. 58*, pp. 312-323 (1950).
4. C. O. Burgess and R. W. Bishop, "Alterations in Cast Iron Properties Accompanying the Use of a Strong Inoculant of the Silicon-Manganese-Zirconium Type", AFS Transactions, *vol. 52*, pp. 671-710 (1944).
5. R. Schneidewind and R. G. McElwee, "Correlation of Properties of Gray Irons", Part II, AFS Transactions, *vol. 58*, pp. 323-332 (1950).
6. R. Schneidewind and R. G. McElwee, "The Influence of Composition on the Physical Properties of Gray Irons", AFS Transactions, *vol. 47*, pp. 491-512 (1939).
7. T. E. Barlow, and C. H. Lorig, "Gray Cast Iron—Tensile Strength, Brinell Hardness, and Composition Relationships", AFS Transactions, *vol. 54*, pp. 545-552 (1946).
8. V. A. Crosby, "Gray Cast Iron Section Size vs. Physical Properties", AFS Transactions, *vol. 54*, pp. 791-794 (1946).
9. H. T. Angus, F. Dunn, and D. Marles, "Properties of Cast Iron in Relation to the Carbon Equivalent Value", AFS Transactions, *vol. 57*, pp. 21-44 (1949).

DUCTILE IRON AS-CAST AND ANNEALED TENSILE PROPERTIES

By A. H. Rauch, J. B. Peck and E. M. McCullough

ABSTRACT

Data from production heats of ductile iron were studied, principally by means of regression analyses. Some of the conclusions resulting from these studies are presented in this paper.

Significant relationships exist between tensile properties and Brinell hardness in as-cast pearlitic-ferritic ductile iron. However, these relationships are strongly affected by changes in composition of the iron. Accurate prediction of the tensile properties of this material requires knowledge of both hardness and composition.

INTRODUCTION

In planning for the production of pearlitic-ferritic ductile iron to be used in the as-cast condition, an investigation was undertaken to determine the ranges of tensile properties that could be expected, and to establish whether or not control of the Brinell hardness of the castings would insure control of the tensile properties of the castings. Encouragement for this approach came from a report that a reasonable indication of the tensile strength of pearlitic-ferritic ductile iron could be obtained from a Brinell hardness reading through the use of an approximate tensile strength-Brinell hardness ratio of 420 to one.[1]

As a preliminary step, simple regression analyses were performed on Y block data from production heats of as-cast ductile iron purchased from a jobbing foundry. Although the 420 to one ratio could not be exactly confirmed, significant relationships, which could be expressed as simple regression equations, were found to exist between all tensile properties and Brinell hardness. However, analyses of covariance showed the elevation of the regression lines to be dependent on the chemical composition of the iron. Therefore, the objectives of the investigation were expanded to include determination of the degree of control of composition necessary to insure control of the tensile properties.

Further investigation was then conducted to determine more precisely, and over wider ranges of variables, the tensile properties-Brinell hardness relationships in as-cast ductile iron, and the effects of composition on these relationships. Data from the initial production heats at the author's company were used in multiple regression analyses of tensile properties on Brinell hardness and chemical composition. In order to relate the findings from this investigation to the ranges of tensile properties to be expected in the castings, a method was developed to calculate the variation of tensile properties resulting from variation of Brinell hardness and composition within specified ranges.

Complete annealing of ductile iron castings of the same chemical composition as those used in the as-cast state has been contemplated. Accordingly, an investigation was undertaken to determine the tensile properties that could be expected, and to determine the factors that would have to be controlled to insure control of the tensile properties in castings of this material.

The tensile strength-Brinell hardness ratio of 420 to one has been reported to be also applicable to type 60-45-10 ductile iron,[1] which is similar to this annealed ductile iron. However, Schneidewind and Wilder[2] and Reynolds, Adams and Taylor[3] have reported experiments indicating that the tensile properties of annealed ductile iron are primarily dependent on chemical composition. Reynolds, Adams and Taylor present equations which are claimed to accurately predict the mechanical properties of annealed ductile iron from composition alone, and further state that the ratio of hardness to strength can be changed by changes in composition.[3]

In order to determine whether Brinell hardness measurements or chemical analysis represented the better method of control of tensile properties, simple regression analyses of tensile properties on Brinell hardness and multiple regression analyses of tensile properties on chemical composition were performed on data from production heats. It was found that chemical composition is the more accurate indication of tensile properties. The multiple regression analysis of tensile properties on chemical composition produced relationships which, when combined with the method for calculation of variation mentioned above, make possible the prediction of the tensile properties of fully annealed ductile iron castings having a composition within specified ranges.

The statistical techniques used in these investigations may not be familiar to some readers. The Appendix to this paper is devoted to the explanation of

A. H. RAUCH is Mgr. Met. Div. and J. B. PECK and E. M. McCULLOUGH are Met., Materials Engrg. Dept., Deere & Company, Moline, Ill.

assumptions underlying these techniques and to proper interpretation of the results.

PROCEDURE

The data for the as-cast ductile iron investigation were obtained from 194 one-in. and three-in. Y-block castings poured from production heats over a three month period. These castings were dumped from the molds at varying intervals of time following solidification in order to obtain a wide distribution of cooling rates. The annealed ductile iron data were taken from 102 one-in. Y-block castings poured from production heats over a four day period. These castings were annealed with the equipment and cycle available for malleable iron, i.e., 6 hr to 1750 F, 10 hr at 1750 F, 5 hr from 1750 F to 1375 F, 11 hr from 1375 F to 1300 F, air cooled to room temperature.

Standard, threaded 0.505 in. test bars were machined from the lower 1 in. of the Y blocks for determination of tensile properties. Yield strengths were determined from stress-strain recordings using the 0.2 per cent strain offset method, and elongations were determined over 2 in. gage lengths. Test bars that fractured at or outside of the gage marks were not included in the investigations. Brinell hardness, microstructure and chemical composition, with the exception of the carbon content of the as-cast material, were determined on the portions of the Y blocks from which the test bars were machined. In the as-cast ductile iron investigation, carbon was determined from chilled carbon pins poured immediately after the Y blocks.

For the annealed ductile iron investigation, the carbon determination procedure was changed to analysis of wafers cut from the Y blocks, after it was discovered that the carbon content of a chilled pin does not always represent the carbon content of a Y block. This subject is covered in a paper referred to in the Appendix. The carbon content reported for as-cast ductile iron is the carbon content of the molten iron, and the carbon content reported for annealed ductile iron is the carbon content of the Y blocks.

The graphite structure in all of the castings included in these investigations was essentially ductile. Castings containing vermicular graphite were rejected. Up to 10 per cent crab graphite was tolerated, although the general level was nil. Figure 1 defines the laboratory's graphite classification. Up to 15 per cent pearlite was considered acceptable in the annealed ductile iron castings. The general level was much lower, nil to 2 per cent. No castings containing primary cementite were included, with the exception of several Y blocks containing traces of cell boundary carbide.

TABLE 1 — RANGES OF VARIABLES STUDIED

Variables	As-Cast Ductile Iron	Annealed Ductile Iron
Hardness, Bhn	179-293	146-174
Tensile strength, psi	74,500-132,500	56,300-69,500
Yield strength, psi	48,500-82,000	36,800-51,000
Elongation, %	3-15	20-28
Pearlite, %	15-97	Nil-15
C, %	3.34-4.08*	3.50-3.80**
Si, %	2.15-3.17	2.15-3.19
Ni, %	0.34-0.90	0.38-0.66
Mg, %	0.030-0.109	0.030-0.119
Mn, %	0.17-0.59	0.28-0.54
Cr, %	0.038-0.088	0.045-0.092
P, %	0.010-0.029	0.012-0.025
Cu, %	0.08-0.12	0.08-0.12

*Analysis of chilled carbon pins, represents carbon content of molten iron.

**Analysis of Y block wafers, represents carbon content of test specimen.

The data were analyzed by means of multiple linear regression. In the as-cast ductile iron investigation, the tensile properties were considered dependent variables, while the Brinell hardness and chemical determinations were considered independent variables. In the annealed ductile iron investigation, the tensile properties and Brinell hardness were considered dependent variables, while the chemical determinations were considered independent variables. The ranges of variables studied in these investigations are shown in Table 1.

A criterion of 95 per cent confidence was used in determining statistical significance of a relationship which, in turn, determined whether or not an independent variable was used in a regression equation. The accuracies of predictions from the regression equations were calculated in the form of 95 per cent confidence limits. Linear approximations to the true parabolic form of confidence limits were used.

AS-CAST DUCTILE IRON

Subject to the qualifications stated in the Appendix, the tensile properties of as-cast pearlitic-ferritic ductile iron can be predicted from the hardness and composition by means of the following regression equations:

Tensile Strength, psi = 488 (Bhn) − 2,730 (% Si) − 6,260.
95% Confidence Limits: ± 5,650 psi. *(1)*

Yield Strength, psi = 259 (Bhn) + 9,740 (% Si) + 4,750 (% Ni) − 36,800 (% Cr) − 45,200 (% Mg) − 20,680.
95% Confidence Limits: ± 3,570. *(2)*

Elongation, % = 8.8 − 0.0920 (Bhn) + 3.84 (% Si) − 22.2 (% Mg) + 3.47 (% C).
95% Confidence Limits: ± 2.9%. *(3)*

In an iron containing 2.60% Si, 0.50% Ni, 0.070% Cr, 0.060% Mg, and 3.80% C, these equations would be:

Tensile Strength, psi = 488 (Bhn) − 13,350. *(4)*

Yield Strength, psi = 259 (Bhn) + 1,730. *(5)*

Elongation, % = 30.6 − 0.0920 (Bhn). *(6)*

Equations (4), (5) and (6) are shown in graphic form in Fig. 2. Figure 3 shows similar equations for four other compositions.

A comparison of equation (1) with the tensile strength-Brinell hardness ratio of 420 to one shows that use of the simple ratio would not lead to serious inaccuracies for irons with the most common composition and hardness ranges. However, examination of equations (1) and (2) shows that the use of a yield strength to tensile strength ratio, for prediction or evaluation of the yield strength of this material, could result in significant errors. The ratio of yield strength to tensile strength depends not only on composition but also on hardness level. Unless these other factors are known, this ratio is meaningless.

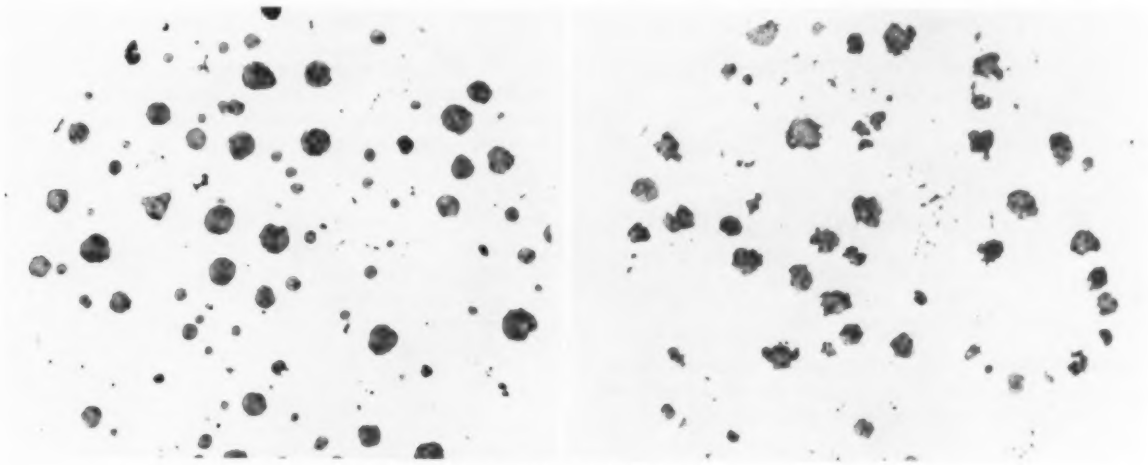
As demonstrated graphically in Fig. 3, the coefficients for chemical composition in equations (1), (2) and (3) may be regarded as the effects of composition on the tensile properties-Brinell hardness relationships. These effects of composition can be rationalized. Increases in the ferrite soluble elements, silicon and nickel, increase the hardness of the ferrite and, therefore, result in a material with less pearlite at a given composite hardness. Increases in these soluble elements also increase the strength and decrease the ductility of the ferrite, although not necessarily at the same rate as the increase in ferrite hardness.

It appears that the tensile strength and elongation depend more upon the amount of pearlite present at a given composite hardness than upon the strength and ductility of the ferrite, whereas the yield strength depends more upon the strength of the ferrite. The absence of nickel from the tensile strength and elongation equations can be attributed to a relatively weak effect in comparison with experimental error. The apparently deleterious effect of increases in chromium or magnesium on yield strength at a given composite hardness can be explained by an increase in hardness of the pearlite due to chromium and magnesium carbides, resulting in a material with the same ferrite strength but less pearlite at a given composite hardness.

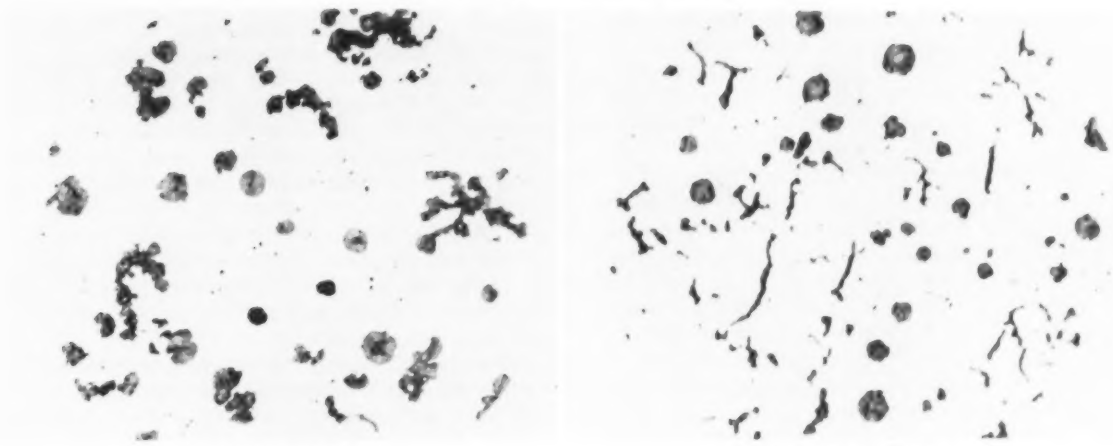
It would be more probable that this effect would be detected in the yield strength regression analysis than in the other regression analyses, because of the relatively greater accuracy of the yield strength regression equation. This hypothesis can also help explain the deleterious effect of increases in magnesium on elongation at a given composite hardness. However, other evidence indicates that this effect is mostly due to an increase in minute amounts of primary cementite with increases in magnesium. The beneficial effect of increases in carbon on elongation at a given composite hardness can then be explained by the recognized ability of increases in carbon to decrease primary cementite.

ANNEALED DUCTILE IRON

Subject to the qualifications stated in the Appendix, the tensile properties and hardness of fully annealed ductile iron can be predicted from the composition by means of the following regression equations:



Nodular graphite, typical variations



Crab graphite — Vermicular graphite

Fig. 1 — Classification of graphite forms found in ductile cast iron. 100 ×.

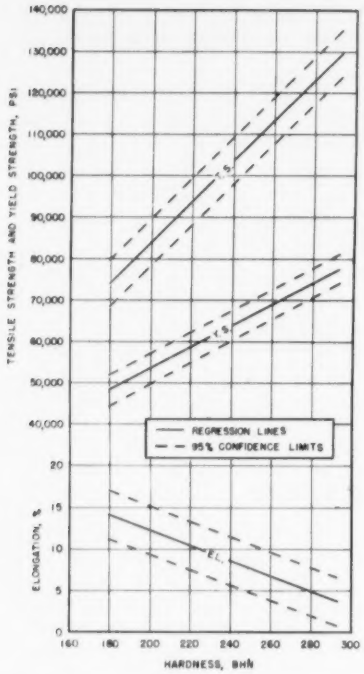


Fig. 2 — (Left) Regression of tensile properties on Brinell hardness for as-cast ductile iron.
C — 3.80% Cr — 0.070%
Si — 2.60% Mn — 0.17-0.59%
Ni — 0.50% P — 0.010-0.029%
Mg — 0.060% Cu — 0.08-0.12%

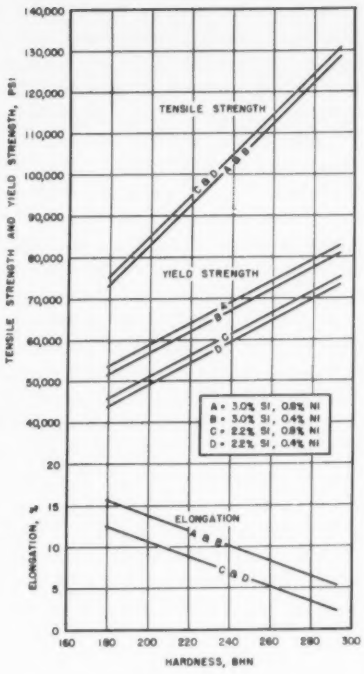


Fig. 3 — (Right) Silicon and nickel content changes effect on the elevation of the regression lines in the regression of tensile properties on Brinell hardness for as-cast ductile iron.
C — 3.80% Mn — 0.17-0.59%
Mg — 0.060% P — 0.010-0.029%
Cr — 0.070% Cu — 0.08-0.12%

Tensile Strength, psi = 76,480 + 8,880 (% Si) + 3,340 (% Ni) − 10,520 (% C).
95% Confidence Limits: ± 1,800 psi. *(7)*

Yield Strength, psi = 59,400 + 11,550 (% Si) + 4,970 (% Ni) + 5,880 (% Mn) − 14,010 (% C).
95% Confidence Limits: ± 1,340 psi. *(8)*

Elongation, % = 85.4 − 6.6 (% Ni) + 11.7 (% Mg) − 16.3 (% C).
95% Confidence Limits: ± 2.6%. *(9)*

Hardness, Bhn = 91 + 25.5 (% Si).
95% Confidence Limits: ± 7 Bhn. *(10)*

The relatively narrow confidence limits associated with these equations indicates that the tensile properties of fully annealed ductile iron are determined principally by composition. In as-cast ductile iron, cooling rate following solidification is an additional variable. The use of Brinell hardness as an independent variable in the regression equations for the as-cast material measures the effects of cooling rate as well as partially measuring the effects of composition. With annealed ductile iron, the use of Brinell hardness as an independent variable is not necessary as this material is essentially annealed, alloyed ferrite, modified by a dispersion of graphite nodules.

The cooling rate following solidification should not be a factor in such a material and the cooling rate following annealing, which can affect the hardness of alloyed ferrite according to Austin,[4] did not vary sufficiently to be a factor. As mentioned earlier in this paper, Brinell hardness does not measure the effects of the alloying elements and the graphite on the tensile properties as well as the composition measures these effects.

The effects of the ferrite soluble elements, silicon, nickel and manganese, correspond reasonably well with the effects expected for solid solution alloys in ferrite. The order of effectiveness of these elements in increasing the strength and hardness of annealed ductile iron corresponds with the order of effectiveness in strengthening ferrite reported by Lacy and Gensamer,[5] and the order of effectiveness in hardening ferrite reported by Bain[6] and Austin.[4] The absence of manganese from equations (7), (9) and (10), and of nickel from equation (10), can be attributed to insufficient variability of these elements in comparison with experimental error.

The absence of silicon from equation (9) may be due to partial cancellation of its effect, in lessening the ductility of ferrite, by its effect in promoting more complete annealing. Generally, quantitative comparisons of the effects of these elements on annealed ductile iron with the effects reported on ferrite show few inconsistencies that cannot be explained.

The effects of silicon and nickel on the tensile properties and hardness of annealed ductile iron reported by Reynolds, Adams and Taylor[3] compare well with those found in this investigation. However, the effects of carbon reported by Reynolds, Adams and Taylor[3] are not consistent with the effects found in this investigation. Most of the apparent disagreement can probably be attributed to different methods of carbon analysis. The data shown in an earlier report[7] indicate that Reynolds, Adams and Taylor used chilled pins for carbon determinations. As mentioned earlier in this paper, the carbon content of a chilled pin does not always represent the carbon content of the tensile test specimen.

The general effect of an increase in carbon is to reduce all tensile properties. This effect is probably due to a combination of the reduction in effective cross-section by the graphite nodules with stress concentration dependent on nodule size and shape. The beneficial effect of magnesium on elongation may be

related to the dependence of stress concentration on nodule shape.

APPLICATION OF EQUATIONS

The regression equations shown in this paper permit direct specification of the factors that control the tensile properties of as-cast and fully annealed ductile iron castings. If the composition of the iron and, in the case of as-cast ductile iron, the Brinell hardness of the castings are allowed to vary only within specified ranges, the mean tensile properties of the castings can be calculated from the mean composition and hardness values by means of the regression equations. The variation in tensile properties of the castings can be calculated by means of a method described in the Appendix.

As an example, consider two groups of ductile iron castings, one group in the as-cast condition and the other annealed. The chemical composition of both groups is specified to be to the mean values and within the limits given in Table 2.

It is also specified that no more than 15 per cent pearlite is present in the annealed castings, and that the hardness of the castings to be used in the as-cast condition is controlled to a mean of 226 Bhn and within 95 per cent confidence limits of 197-255 Bhn. It is further specified that, in all cases, the graphite form is essentially nodular, and that no more than a trace of primary cementite exists. The means and ranges of the inherent tensile properties of the castings would then be like those given in Table 3.

Minimum properties designations for these irons would probably be 80-50-06 for the as-cast iron, and 60-40-20 for the annealed iron. It is readily apparent from the equations, and from Fig. 3, that ranges of tensile properties substantially different from those shown can be obtained. These ranges of tensile properties refer to the inherent properties of the castings as measured by standard test specimens machined from adequately fed sections. They do not refer to the surfaces of castings, to areas containing voids, slag or carbon flotation, or to the geometric centers of most sections. With these exceptions, test bars machined from production castings have been found to conform reasonably well to predictions.

CONCLUSIONS

The tensile properties of as-cast pearlitic-ferritic ductile iron can be predicted with reasonable accuracy from the Brinell hardness and composition. The most direct and effective way of insuring control of the inherent tensile properties of castings of this material is to specify composition ranges and Brinell hardness ranges for the castings. Obviously, additional specifications concerning such factors as graphite shape and permissible amount of primary cementite are also necessary.

The tensile properties of annealed ductile iron can be predicted with reasonable accuracy from the composition. The most direct and effective way of insuring control of the inherent tensile properties of castings of this material is to specify composition ranges. Again, it is obvious that additional specifications concerning such factors as graphite shape and permissible amounts of primary cementite are necessary. For this material, it is also necessary to specify the amount of residual pearlite allowable in the castings.

TABLE 2 — CHEMICAL COMPOSITION MEAN VALUES

Composition, %	Mean	95% Confidence Limits
C*	3.80	3.60-4.00
Si	2.60	2.40-2.80
Ni	0.50	0.40-0.60
Mg	0.060	0.040-0.080
Mn	0.50	0.35-0.65
Cr	0.070	0.052-0.088
P	0.016	0.008-0.024
Cu	0.10	0.09-0.11

*Carbon content of the molten iron.

TABLE 3 — INHERENT TENSILE PROPERTIES, MEANS AND RANGES

	As-Cast Ductile Iron		Annealed Ductile Iron	
Property	Mean	95% Confidence Limits	Mean	95% Confidence Limits
Tensile Strength, psi	96,930	81,550-112,310	62,490	59,380-65,600
Yield Strength, psi	60,260	51,550-68,970	43,250	39,550-46,950
Elongation, %	9.9	5.8-14.0	*23.3	20.4-26.2

ACKNOWLEDGMENTS

The authors gratefully acknowledge the cooperation and assistance given by John Deere Malleable Works, who supplied the castings used in these investigations. Appreciation is extended to the I.B.M. Processing Dept., Deere & Company, for performing on an electronic computer the lengthy calculations involved in multiple regression analysis. The authors also thank the personnel of the Materials Engrg. Dept., who conducted the mechanical tests, chemical determinations and metallographic examinations, and those who provided the guidance and encouragement for this program.

REFERENCES

1. *Engineering Properties and Application of Ductile Iron*, International Nickel Co., p. 17, 1957.
2. R. Schneidewind and H. H. Wilder, "Commercial Experience with Higher Silicon Nodular Irons," AFS TRANSACTIONS, *vol. 60*, pp. 322-329, 1952.
3. C. C. Reynolds, C. M. Adams and H. F. Taylor, "Prediction of Mechanical Properties from Chemical Composition for Fully Annealed Ductile Cast Iron," AFS TRANSACTIONS, *vol. 61*, pp. 510-515, 1953.
4. C. R. Austin, "Effect of Elements in Solid Solution on Hardness and Response to Heat Treatment of Iron Binary Alloys," *A.S.M. Transactions, vol. 31*, pp. 321-339, 1943.
5. C. E. Lacy and M. Gensamer, "The Tensile Properties of Alloyed Ferrites," *A.S.M. Transactions, vol. 32*, pp. 88-110, 1944.
6. E. C. Bain, *Functions of The Alloying Elements in Steel*, A.S.M., pp. 65-67, 1939.
7. C. C. Reynolds and H. F. Taylor, "Mechanical Properties of Spherulitic Graphite Cast Iron," AFS TRANSACTIONS, *vol. 60*, pp. 687-713, 1952.

APPENDIX

Multiple linear regression analysis is a standard statistical technique which enables the analyst to determine whether or not statistically significant linear relationships exist between dependent and independent

variables, calculate the best linear equations for predicting values of the dependent variable from knowledge of the independent variables and measure the accuracy of these predictions. The derived regression equations are not functional equations, and should not be used to predict values of an independent variable from knowledge of the other variables.

As stated in the description of procedure, a criterion of 95 per cent confidence was used in these investigations for determining statistical significance of a relationship. Only those independent variables significantly related to the dependent variables were included in the regression equations. Therefore, there are less than five chances in 100 that no relationship exists when one is shown, or that the direction of relationship shown is wrong. Lack of statistical significance, and the absence of an independent variable from a regression equation, does not mean that this variable has no effect on the dependent variable in question.

The proper interpretation is that the existence of a relationship could not be demonstrated statistically with a reasonable degree of certainty from the available data for one or a combination of the following reasons:

1) The variation in the independent variable was too small in comparison with experimental error.
2) The relationship is too weak in comparison with experimental error.
3) The curvature of the relationship is too great for the linear assumption.

On the other hand, a relationship shown by a regression analysis to be statistically significant does not constitute proof of cause and effect. A significant relationship only demonstrates that a high degree of association existed during the period and under the circumstances in which the data were collected. However, for reasons of convenience, these relationships are occasionally referred to as causes and effects in this paper.

It is also stated in the description of procedure that the accuracies of predictions from the derived regression equations are presented in the form of 95 per cent confidence limits. These limits should contain 95 of 100 measured values of the dependent variables. Predictions from a regression equation are valid only over the ranges of independent variables studied. Extrapolation beyond these ranges, which, for these investigations, were presented in Table 1, could be misleading.

Care should also be taken, in predicting from a regression equation, that the ranges of variables not shown in the regression equation, yet suspected of affecting the dependent variable, do not differ substantially from the ranges studied. For instance, copper and phosphorus are both known to affect the tensile properties of ductile iron, yet neither is shown in any of the regression equations. If these regression equations are used for irons with copper and phosphorus contents substantially different from the ranges encountered in these investigations, adjustments in elevation of some of the regression lines would be necessary.

As another example, manganese is not shown in the regression equation of tensile strength of annealed ductile iron on composition, yet it would not be advisable to predict from this regression equation for irons with manganese contents much beyond the range investigated.

The variation in a dependent variable resulting from variation of the independent variables within stated limits can be computed by means of equations of the following type:

$$\sigma_{TS}^2 = (b_{Bhn}\sigma_{Bhn})^2 + (b_{Si}\sigma_{Si})^2 + \sigma_E^2$$

where

σ_{TS}^2 = The total variance in tensile strength.

b_{Bhn} = The coefficient for Brinell hardness in equation (1).

σ_{Bhn} = The standard deviation of Brinell hardness, a value dependent on control limits.

b_{Si} = The coefficient for silicon in equation (1).

σ_{Si} = The standard deviation of silicon content, a value dependent on control limits.

σ_E^2 = The variance of a point predicted from equation (1), contains the experimental error.

The above equation applies to the tensile strength of as-cast ductile iron. Similar equations apply to the other dependent variables investigated. Such calculations assume an approach to normality in the distribution of each variable. It is also assumed that the so-called independent variables are truly independent.

An objection may arise that, in the case of as-cast ductile iron, hardness is dependent on composition, yet is considered an independent variable along with the composition. This objection is valid to a limited extent. However, hardness is also varied independently of composition by means of cooling rate variation, which, in turn, is dependent on section size and mold dumping time.

In the case of annealed ductile iron, carbon is sometimes not independent of silicon. As stated in an earlier section of this paper, the carbon determinations in the annealed ductile iron investigation differ from those in the as-cast ductile iron investigation, in that the former represent the carbon content of the castings whereas the latter represent the carbon content of the molten iron. According to a paper soon to be published by A. H. Rauch, J. P. Peck and G. F. Thomas, the carbon equivalents (% C + 1/3% Si) of medium section size castings, based on carbon determinations from wafers cut from the castings, have a top limit of approx. 4.55 per cent.

No difficulty arises in calculation of variation, if the carbon and silicon ranges in the molten iron are such that a carbon equivalent of 4.55 per cent is not reached. If the carbon and silicon ranges are such that the carbon equivalent of the molten iron seldom falls below 4.55 per cent, the carbon content may be considered wholly dependent on the silicon content, carbon may be eliminated from the regression equation and a new coefficient for silicon may be computed. No solution is presented for intermediate cases.

University of Illinois Facilities Open to Foundry Instructors Seminar

■ Foundry and patternmaking facilities of the University of Illinois, rated as one of the nation's most active at the university level, will be available to secondary school instructors and supervisors attending the AFS 4th Annual Foundry Instructors Seminar.

The Seminar will be held June 18-20 at Urbana, Ill., with a field trip to the GMC Central Foundry Division plant at Danville, Ill.

Each year instructors attend to be informed on the latest developments in foundry practices and to learn how these improvements can be incorporated into their school program. Included in the program will be: workshops in melting, molding, coremaking, sand testing and temperature measurement and control; technical sessions and demonstrations on teaching aids, curricula, shop layout, laboratory equipment and new casting and molding techniques; pouring of metal by those attending.

In addition to assisting secondary school teachers in conducting and planning their foundry and patternmaking programs, the Seminar furnishes instructors with vocational guidance and instructional material to encourage young men to enter the foundry industry.

The Seminar is planned by the Foundry Instructors Seminar Committee of the AFS Education Division and in its three years of operation has become one of the most active projects of the division.

Arrangements at the University of Illinois are being made by Prof. James L. Leach, Department of Engineering, a member of the AFS Education Division, and Robert K. Newton, supervisor, Engineering Extension Division at the university.

Previous Seminars have been held at Michigan State University in 1956 and 1957 and at Case Institute of Technology in 1958.

Technical sessions for the AFS 4th Annual Foundry Instructors Seminar will be held at the **Illini Union Building,** University of Illinois.

Committee Preparing Recommendations To Air Pollution Control Association

■ Preparation of recommendations to the Air Pollution Control Association is being made by its committee on foundries headed by H. J. Weber, AFS Director of Safety, Hygiene and Air Pollution Control.

"These recommendations, will in all probability, materially affect the foundries—if the industry doesn't take action regarding air-pollution legislation, some other group will," says Weber.

So that others may understand the air-pollution problem in foundries, reports will be made on foundry operations and nomenclature. Specific operations such as investment-casting procedures, non-ferrous practice, melting practice for malleable shops and electric-furnace melting will be written by committee members.

Additional assignments include:

- Practical steps foundrymen can take to minimize their air pollution problems other than installation of dust collectors.
- Evaluate effectiveness of control equipment available and offered by manufacturers to control foundry effluents.
- Recommend instruments and techniques for measuring foundry emissions.

news and views

CONTENTS

Instructors Seminar .. 117

Castings Congress ... 118

Castings Show 120

California Regional .. 123

Texas Regional 124

T&RI Courses 125

International Congress 126

Chapter News 127

Chapter Meetings ... 133

Congress Papers Outline Future . . . . .

■ Blueprints for the foundry future will be unfolded in approximately 100 technical papers to be presented at the AFS 63d Castings Congress.

Papers will be presented daily by AFS divisions and general interest committees during the combined Engineered Castings Show and Castings Congress.

Will there be radical changes in melting in gray iron foundries? European foundries are making their gray iron directly from ore. How it is being done on a commercial basis will be explained at the Castings Congress.

What economies can be expected from a linear program applied to the selection of furnace charges? Low-cost, high-speed electronic brains are doing this for larger foundries. Pencil and paper techniques are also explained in this important Castings Congress paper.

What are the problems in designing press-forge castings? A paper will tell foundrymen and casting designers how to push steel castings into new frontiers through the combination of two techniques.

In order to have the technical program function smoothly, authors and technical session chairman will meet daily at breakfast. The day's program will be reviewed and arrangements made for each session.

Supplementing the technical talks will be shop courses and roundtable luncheons.

On Monday, the Light Metals and Malleable Divisions will hold luncheons as well as the AFS Board of Directors. A Malleable Division shop course will be held at 4:00 pm and a Sand Division Shop course at 8:00 pm.

On Tuesday, luncheons will be held by the Brass and Bronze Division and the Pattern Division. At 4:00 pm, the Malleable Division and Gray Iron Division will both conduct shop courses. Tuesday's evening activities will include a Canadian Dinner and a Sand Division Dinner.

Wednesday morning will be devoted to Society activities including *the Annual Business Meeting*; the Hoyt Lecture, *The Control of Quality in the Brass Foundry* by Harry St. John; Apprentice Contest Awards; and presentation of Awards of Scientific Merit and Service Citations.

A Management luncheon and Die Casting and Permanent Mold Division round-table luncheon will be held Wednesday noon. Technical sessions resume at 2:00 pm Wednesday with a Gray Iron Division shop course scheduled for 4:00 pm.

The Annual AFS Banquet will be held Wednesday evening. Included will be an outstanding speaker to be announced and presentation of the AFS Gold Medals.

Thursday, luncheons will be held by the Steel Division the Past Presidents and the Ductile Iron and Gray Iron Divisions will co-sponsor a luncheon. No shop courses are scheduled for Thursday afternoon or Friday in the tentative program.

Papers for Designers

Each major AFS division has obtained papers directed toward designers of castings. Typical papers tentatively scheduled are:

How Aircraft Designers Look at Light Metals Castings.
Design Engineering as Related to Magnesium Castings.
Principles for Producing Sound Light Metal Castings.
Foundry Designing for Steel Castings.
Help for the Design Engineer or Foundryman.
Design and Welding of Castings for Steam Turbine Castings.
Quantitative Measurement of the Effects of Pearlite and Graphite on the Machinability of Gray Cast Iron.
Ductility and Strength of High-Carbon Gray Iron.
Preliminary Appraisal of Bending Techniques for Evaluation of Cast Material and Construction.
Martensitic White Irons for Abrasion Resistant Castings.
Some Foundry Problems in the Development of a New Propeller Alloy.
Evaluation of Cast Surface for Roughness Standard.
A Rationalization of the Effect of Mass on the Tensile Properties of Castings.
Practical Planning for Non-Destructive Testing by use of Radioisotopes.
Malleable Iron—A Magnetic Alloy.
Heat Treatment of Ductile Iron.
Some Properties of Wrought and Cast High Strength Steel.
Requirements for Quality Castings in the Aircraft Industry.
Tensile Properties of As-Cast and Annealed Ductile Iron.
Interrelation between Stress Concentration and Castability.
Electrical Conductivity of Sand Cast Copper-Base Alloys.

Other Congress Papers

Modern Quenching Oils and Techniques for Heat Treatment.
Foundries Can Produce Their Own Gray Iron Directly from Ore.
Chemical Analysis of Gray Iron.
Utilization of Radioisotopes in Foundry Industry.
X364 Die Casting Alloy.
A Summary of Aluminum and Permanent Mold Practice.
Constant Volume Solidification Sample for Rapid Measurement of Gas in Aluminum.
A Discussion on Modern Alloy.
Quality Control for Ductile Iron Castings.
Correlation of Radiography, Microstructure and Mechanical Properties of Cast Thoriated Magnesium.
Specialized Quality Statistical Controls Improve Customer Satisfaction.
Ultrasonic Attenuation in Cast Aluminum.
Factors Influencing the Soundness of Gray Iron Castings.
Tempering of Molding Sand.
Dimensioning of Sand Casting Risers.
Effect of Molybdenum on Elevated Temperature Properties of Gray Iron.
Effect of Melting Variables on the Properties of Malleable Irons.
Permanent Molding of Gray Iron.
Reclamation and Dimensional Accuracy of Sodium Silicate Bonded Sand.
Sand Movement Compaction in Green Sand Molding.
Experimental Determination of Specific Surface and Grain Shapes of Foundry Sands.
Rapid Hydrogen Determination for Steel Foundry Control.
Critical Sodium Silicated Sand Formulations for Optimum CO_2 Molding.
Timing of Expansion Scab Formation.
Hot Cracking for Light Metal Casting Alloys.
Effect of Starch Content on a Rammed Graphitic Mold Material for Casting Titanium.
Linear Program Applied to Economic Selection of Materials in Furnace Charge.
Designing for Press-Forge Castings.
Solidification Time of Simple Shaped Castings.
Carbon Flotation in Ductile Iron.
Effect of Bonding Clays on Pinholes in Malleable Castings.
Production of Ductile Iron in the Basic Direct Arc Furnace.
The Control of Quality in the Brass Foundry.
Green Tensile Strength and Shear Strength of Molding Sands.
Effect of Mold Materials on the Cooling Rate and Physical Properties of Cast Metals.
Porosity—Inclusions—Pinholes in Malleable Iron.
Effect of Tin on the Structure and Property of Flake and Nodular Graphite Cast Irons.
Aluminum Castability and Dissolved Gases Measurement and Improvement.
Solidification of Gray Iron.
Red X20, A Hypereuctetic Aluminum-Silicon Alloy.
Veining in Nickel Silver.
Foundry Characteristics of Manganese-Vanadium—Molybdenum Age-Hardening Austenitic Steel.

. . . . . Authors Tell Latest Advances

Tentative Schedule of Technical Sessions
AFS Castings Congress & Engineered Castings Show
April 13-17, 1959 . . . Hotels Sherman & Morrison

TIME	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
8:00 am	Authors Breakfast	Authors Breakfast	Authors Breakfast	Authors Breakfast	Authors Breakfast
8:30 am	Registration opens 8:00	Registration opens 8:30	Registration opens 8:30	Registration opens 8:30	Registration opens 8:30
9:00 am	Exhibits open 9:00-5:30	Exhibits open 9:00-5:30		Exhibits open 9:00-5:30	Exhibits open 9:00-4:00
9:30 am to 11:30 am	Light Metals Malleable Pattern	Brass & Bronze Pattern Malleable SH&AP T&RI Trustees	Annual Business Meeting & Hoyt Lecture Exhibits open 11:30-5:30	Steel Ductile Iron Fundamental Papers Die Casting & Permanent Mold	Sand Heat Transfer Ductile Iron Fundamental Papers
12:00 noon	Light Metals Luncheon Malleable Luncheon	Brass & Bronze Luncheon Pattern Luncheon Board of Directors Luncheon & Meeting	Management Luncheon Die Casting & Permanent Mold Luncheon	Steel Luncheon Ductile and Gray Iron Luncheon Past Presidents Luncheon	
2:00 pm to 4:00 pm	Brass & Bronze Sand Pattern	Light Metals Education Industrial Engineering & Cost	Steel Die Casting & Permanent Mold Gray Iron	Sand Heat Transfer Ductile Iron Fundamental Papers	Gray Iron Plant & Plant Equipment
4:00 pm to 5:30 pm	Brass & Bronze Malleable Shop Course	Sand Light Metals Malleable Shop Course Gray Iron Shop Course	Industrial Engineering & Cost Die Casting & Permanent Mold Gray Iron Shop Course Sand	Steel Gray Iron	
6:00 pm		Sand Dinner (6:30)			
7:00 pm		Canadian Dinner	Annual Banquet	Alumni Dinner	
8:00 pm to 10:00 pm	Sand Shop Course				

Tentative Hot Shell Deformation Test.
Deoxidation Defects in Steel Castings.
Metal Cost, Its Practical and Analytical Evaluation in Aluminum Die Castings.
Proper Gating through the Use of Cobalt 60.
Profit Management through Cost Control.
Foundry Resin and Application Techniques for Shell Molds and Cores.
Preparation and Control of a Moisture-Free Green Sand.
Copper in Cast Iron.
Audiometric Testing Programs in Foundry Noise Control.
How to Avoid Sand Segregation.

Housing

Housing applications should be mailed to:
AFS Housing Bureau
Suite 900
134 N. La Salle St.
Chicago 2, Ill.

Hotels Sherman (left) and **Morrison** located in Chicago's loop. The Engineered Castings Show and technical sessions of the Castings Congress will be held at the Sherman and the Morrison.

APRIL

Reserve 12 13 14 15 16 17 18

For Engineered Castings Show

■ Sixteen of the nation's largest casting producing states, including seven of the eight largest casting producing cities, will be represented at the AFS Engineered Castings Show to be held April 13-17.

More than 60 exhibitors represent the country's progressive foundries, patternshops and producers of testing equipment and supplies for quality control. Their exhibits will demonstrate how castings can do the job better—for less.

Their message is directed to the 50,000 casting designers and buyers who have been invited to see what can be produced by metalcasting techniques.

The Engineered Casting Show differs from the biennial equipment show by directing its attention to all industries using castings. Its objective is to demonstrate the capabilities of castings. The Show provides an assist to the foundry industry by creating a castings show place and building an audience previously contacted only on a limited basis.

Exhibitors will be able to contact more potential buyers during five days than possible with other sales media.

The Show presents an opportunity for designers and buyers to see, study and discuss actual castings and to learn the advantages of cast metal parts. Exhibits will show case histories of how parts have been redesigned or converted from other means of fabrication. Emphasis will be put on what castings can provide—longer service, less weight, better finish, lower production costs, lower maintenance costs, decreased machining time and longer tool life.

Technical papers, presented at the 63d Castings Congress which runs concurrently, will provide casting buyers and designers with the latest technical information available. Each AFS division will sponsor Congress papers having specific interest to designers.

Space is Available

Space is available at the Engineered Castings Show. For further details write to W. N. Davis, Exhibit Manager, AFS Central Office, Golf and Wolf Roads, Des Plaines, Ill. AFS is equipped to advise exhibitors on how to get the most from the Engineered Castings Show participation.

Who is Eligible?

■ Producers of castings for sale.

■ Producers of patterns and dies for metal casting.

■ Manufacturers of laboratory, testing and inspection equipment for control of casting quality.

■ Producers of metals and alloys inherent in quality castings.

Exhibitors

Adirondack Steel Casting Co., Watervliet, N.Y.
American Brake Shoe Co., Engineered Castings Div., New York.
American Smelting & Refining Co., New York.
American Steel Foundries, Chicago.
Apex Smelting Co., Chicago.
Morris Bean & Co., Yellow Springs, Ohio.
Bendix Aviation Corp., Teterboro, N.J.
Berlin-Chapman Co., Berlin, Wis.
Brillion Iron Works, Inc., Brillion, Wis.
Brush Beryllium Co., Cleveland.
Buckeye Brass & Mfg. Co., Mansfield, Ohio.
Casting Engineers, Inc., Chicago.
Chicago Foundry Co., Chicago.
Consolidated Foundries & Mfg. Corp., Chicago.
Crucible Steel Casting Co., Milwaukee.
Crucible Steel Casting Co., Cleveland.
Curto-Ligonier Foundry, Melrose Park, Ill.
Devcon Corp., Danvers, Mass.
Dixie Bronze Co., Birmingham, Ala.
Doehler-Jarvis Div., National Lead Co., New York.
Dow Chemical Co., Midland, Mich.
East St. Louis Castings Co., East St. Louis, Ill.
Engineered Precision Casting Co., Matawan, N.J.
Fabricast Div., General Motors Corp., Bedford, Ind.

Main exhibit hall at **Sherman Hotel** where Engineered Castings Show will be held April 13-17.

Ride the Upswing in '59 Exhibit at the Castings Show

Gillett & Eaton, Inc., Lake City, Minn.
Hampden Brass & Aluminum Co., Springfield, Mass.
Benj. Harris & Co., Chicago Heights, Ill.
Harsch-Ebaloy Foundries Co., Rockford, Ill.
Hica, Inc., Shreveport, La.
Kaiser Aluminum & Chemical Sales, Inc., Chicago.
Keokuk Steel Casting Co., Keokuk, Iowa.
H. Kramer & Co., Chicago.
R. Lavin & Sons, Inc., Chicago.
Lindgren Foundry Co., Batavia, Ill.
Love Bros., Inc., Aurora, Ill.
Lynchburg Foundry Co., Lynchburg, Va.
Magnaflux Corp., Chicago.
Michiana Products Co., Michigan City, Ind.
Michigan-Standard Alloy Casting Co., Detroit.
Mid-Continent Steel Casting Corp., Shreveport, La.
Misco Precision Casting Co., Whitehall, Mich.
Motor Castings Co., Milwaukee.
Mueller Industries, Inc., Aurora, Ill.
Neenah Foundry Co., Neenah, Wis.
Paxton-Mitchell Co., Omaha, Neb.
Pelton Steel Casting Co., Milwaukee.
Pyott Foundry & Machine Co., Aurora, Ill.
Quality Aluminum Casting Co., Waukesha, Wis.
Rausch Mfg. Co., St. Paul, Minn.
Roessing Bronze Co., Pittsburgh, Pa.
Rolle Mfg. Co., Lansdale, Pa.
Scientific Cast Products Corp., Cleveland.
Shaw Process Development Corp., Div. British Industries Corp., Port Washington, N.Y.
Sipi Metals Corp., Chicago.
Sivyer Steel Casting Co., Milwaukee.
Southern Precision Pattern Works, Inc., Birmingham, Ala.
Stahl Specialty Co., Kingsville, Mo.
Superior Foundry, Inc., Cleveland.
Swedish Crucible Steel Co., Detroit.
Universal Castings Corp., Chicago.
Universal Foundry Co., Oshkosh, Wis.
Vanadium Corp. of America, New York.
WaiMet Alloys Co., Detroit.
Western Foundry Co., Holland, Mich.
Waukesha Foundry Co., Waukesha, Wis.

Getting Most from Exhibit

To get the maximum results from the Show, AFS makes the following recommendations to exhibitors:

Shipping and installation—Ship early and notify all shipments in advance, for checking and tracing. Mark all shipments clearly. Order all power requirements and other utilities well in advance. Assign one man in the organization to receive and be familiar with all Show bulletins, details, rules and regulations.

Booth management—Keep your booth occupied at all times. Send your most qualified men to the booth. See that all products and applications are well identified as to tolerances, physical and chemical properties, weight savings and other pertinent data. Complete files of technical literature are important. Use inquiry cards for follow-up purposes.

Daily sales conferences—Plan a daily sales conference throughout the Show with all exhibitors representatives present. Go over prospects questions asked and jobs under consideration. Correct mistakes made, check literature supplies and make assignments for the following day.

See it at the Show

This 8700-lb quality gray iron casting replaced a weldment. **Engineered Castings Show** will demonstrate how castings have replaced other methods of fabrication.

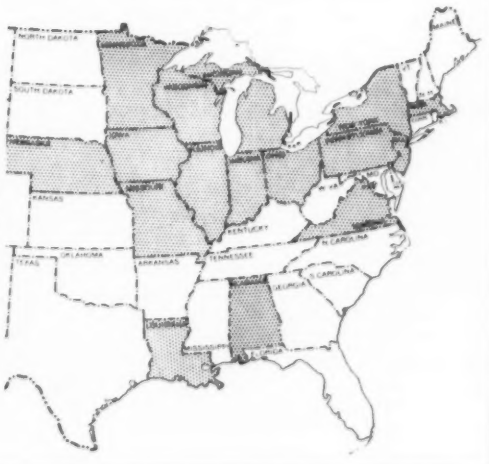
■ Lindgren Foundry Co., Batavia, Ill., will exhibit this 8700-lb quality gray iron casting—a component of a centrifugal extractor used in food, petroleum, chemical and mining industries. Formerly a weldment, Lindgren now casts these extractors from four different sets of all-in-core pattern equipment. The heaviest in the series weighs 10,000 lb; the lightest, 800 lb.

Fabricating these from heavy steel plate involved numerous welding operations and considerable floor space.

Advantages of the casting include:

- Cuts machine time in half.
- Yields superior physical properties.
- Quiets operations due to damping qualities.
- Doubles production with smaller work force.

In addition to the extractor, previously fabricated bearing caps, hinge and latch blocks, and seal housings are now made by Lindgren in gray iron or ductile iron.



Map shows states represented by exhibitors at the **Engineered Castings Show** to be held April 13-17 in Chicago in conjunction with the **63d Castings Congress.**

Emphasis at both the **Castings Show** and **Castings Congress** has been placed on telling the advantages of using cast metal products as components and end products.

Chicago was chosen as the convention site because of the concentration of industry, adequate housing, exhibit space and central location.

Show Hours

Monday	9-5:30
Tuesday	9-5:30
Wednesday	11:30-5:30
Thursday	9-5:30
Friday	9-4:00

Rochester Fights To Save Courses

■ Loss of the only technical high school level foundry and patternmaking courses in the nation's most populous state is a distinct possibility.

How to save this program at Edison Technical and Industrial High School, Rochester, N. Y., is now being studied by a Foundry Advisory Committee which will report to the Rochester Board of Education.

Edison's foundry and patternmaking courses, a part of the school's metals trades department, were installed in 1940. The foundry and patternmaking facilities are now separate. Patternmaking is taught in the main building while the foundry is located a block away in the basement of a former trade school building now converted to a grammar school. It has been proposed that the space now occupied by the foundry be used for other purposes.

A one year's extension has been granted the foundry while the problem is studied by a Foundry Advisory Committee. Either the foundry will have to be abandoned or moved to a building to be constructed adjoining the main building.

The committee is urging construction of the building and installation of new equipment.

Ralph E. Betterley, AFS Education Director, attended the January committee meeting at the request of Harold Hershey, department head, metal trades, Edison Technical and Industrial High School.

Advantages of retaining the program, as outlined by Betterley were:

- The foundry and patternmaking program provides salable skills for the industrial graduate going directly to industry.
- It provides the technical graduate with the necessary practical laboratory training when he is planning to enter engineering school.
- It provides a very practical background for the student pursuing a two-year program at junior college or a technical institute.
- Industry is constantly seeking engineers who have a practical as well as theoretical background.
- Since all graduates do not enter college, the metalcasting industry needs a source of personnel having some basic training in the field.
- With increased technology and mechanization necessary in the metalscasting industry, foundry and patternmaking work has become more of a science than a skill.

AFS National Director William D. Dunn, Oberdorfer Foundries, Inc., Syracuse, N. Y., and Rochester Chapter Chairman Anthony V. Vecchiotti, The Anstice Co., Rochester, N. Y., have also assisted the Foundry Advisory Committee.

Members of the Foundry Advisory Committee are:

Donald Webster, American Laundry Machine Co., Rochester, N. Y.

Walter G. Brayer, Bausch & Lomb Optical Co., Rochester, N. Y.

Charles Vaughn, Ritter Dental Mfg. Co., Rochester, N. Y.

Alfred Murrer, Gleason Works, Rochester, N. Y.

William Olsen, principal, Edison Technical and Industrial High School.

Fletcher Miller, chief consultant of technical and industrial education, Rochester Board of Education.

Harold H. Hershey, department head, metal trades, and foundry and patternmaking instructor.

Webster, Brayer, Vaughn and Murrer are AFS members and past presidents of the Rochester Chapter. Hershey is also an AFS member.

Convention Papers Good Source for Local Programs

■ A frequently unused but highly recommended source of materials for chapter program committees are the numerous papers, panels, shop courses and round-table sessions sponsored at the annual AFS Conventions by the AFS Divisions.

Such material can be developed into outstanding chapter programs utilizing local speakers and panels when original authors are not available.

March 16 Closing Date for AFS Apprentice Competition

■ March 16 is the closing date for entries in the national competition of the AFS 1959 Robert E. Kennedy Memorial Apprentice Contest. All entries must be shipped prepaid to Prof. Roy W. Schroeder, University of Illinois, Navy Pier, Chicago. Contest chairmen are requested to notify Prof. Schroeder or the AFS Central Office at the time of shipping for tracer purposes.

Competition is held in five divisions – metal patternmaking, wood patternmaking, iron molding, steel molding and non-ferrous molding. Winners in each of the first three places in each of the divisions receive: 1st place, $100; 2d place, $75; 3d place $50.

First and second place winners in each division will be invited to attend the Annual Convention and to receive their awards in person. The Society will assume the round-trip travel expense to and from Chicago. All other expenses are to be assumed by the winner, his company or local chapter.

Certificates of recognition, signed by AFS President L. H. Durdin, will be presented to all winners in each national contest division.

All 1959 contest entries are the property of the AFS Apprentice Contest Committee. Requests for return of entries must be made at the time of shipment for judging purposes. All entries returned will be shipped collect.

Entries awarded 1st, 2d or 3d place prizes cannot be returned earlier than 90 days following Convention.

Judging

Judging of national contest entries is conducted on a point-score basis determined by the Apprentice Contest Committee.

Wood Patternmaking

Accuracy according to drawing	35-max.
Moldability	35 max.
Workmanship	20 max.
Time	10 max.
Total	100 max.

Metal Patternmaking

Acuracy according to drawing	50 max.
Workmanship	30 max.
Time	20 max.
Total	100 max.

Molding Division

Gates & Risers	20 max.
Yield	10 max.
Cleanability	10 max.
General appearance	20 max.
Time	15 max.
Soundness	25 max.
Total	100 max.

CaliforniaRegional to be March 13-14

■ General and division sessions covering a wide range of foundry subjects will be presented at the California Regional Foundry Conference to be held March 13-14 at the Huntington - Sheraton Hotel, Pasadena, Calif.

Sessions will be held on steel, iron, non-ferrous, magnesium, aluminum, patternmaking and cleaning room topics as well as subjects of general interest.

The conference is sponsored by the AFS Southern and Northern California Chapters with the Southern California Chapter serving as host.

A luncheon and dinner are scheduled for Friday and a luncheon also arranged for Saturday.

A two-day ladies program will be held with a tour on Friday and a luncheon and fashion show on Saturday.

E. G. Gaskell, Ace Foundry, Ltd., Huntington Park, Calif. is General Conference Chairman and Paul Bergman, Westlectric Castings, Inc., Los Angeles, is Technical Section Chairman.

The tentative program:

FRIDAY, MARCH 13

9:00 am—Registration.

10:00 am—Molding Symposium.

Shell Molding — Walter Dunn, Pacific Alloy Engineering Corp., El Cajon, Calif.

Ceramic Molding — Leonard W. Dean, Brea Alloys & Mfg. Co., Brea, Calif.

Sodium Silicate — Frank Brewster, Brumley-Donaldson Co., Huntington Park, Calif.

12 noon—Luncheon. Speaker, AFS President L. H. Durdin.

1:30 pm—Steel.

Sand and Related Facts, Hubert Chappie, National Supply Co., Torrence Calif.

1:30 pm—Iron.

The Future of Castings in this Moving World, John M. Anspach, Mechanite Metal Corp., New Rochelle, N. Y.

1:30 pm—Bronze.

General Non-Ferrous Foundry Practice Norman Barnett, M. Greenberg's Sons, San Francisco.

3:00 pm—Ductile Iron.

Ductile Iron—It's Past, Present and Future—Frank Brendler, Stanley Foundries, Inc., Huntington Park, Calif.

3:00 pm—Aluminum.

Some Aspects of Molding and Pouring Aluminum—George Stewart, East Bay Brass Foundry, Richmond, Calif.

5:30 pm—Fellowship Hour.

7:00 pm—Dinner.

Industry and the Air Force Accident Prevention Program, Major General Joseph D. Caldara, Director, Flight Safety Research, Norton Air Base, San Bernardino Calif.

SATURDAY, MARCH 14

10:00 am—Induction Melting Symposium.

Non-Ferrous speaker — A. W. Nash, A. W. Nash Co., Los Angeles.

Steel speaker — J. William Mitchell, Utilities Steel Foundry, Los Angeles.

Iron speaker — Merlin Hartman, Dayton Foundry, Hollydale, Calif.

10:00 pm—Pattern.

Tomorrow's Castings—A Challenge to Pattern Design, Paul C. Ricks, AiResearch Mfg. Co., Los Angeles.

12 noon—Luncheon.

1:30 pm—Ferrous.

New Developments in Equipment for Melting and Charging, Harold Schwengel, Modern Equipment Co., Port Washington, Wis.

1:30 pm—Magnesium and Aluminum.

Today's Problems in Magnesium Castings, William Bailey, AiResearch Mfg. Co., Los Angeles.

The Present and Future of Aluminum Castings, Anthony Polizzotto, A&M Casting Co., South Gate, Calif.

1:30 pm—Cleaning Room.

Reducing Blast Cleaning Costs, G. O. Pfaff, Wheelabrator Corp., Mishawaka, Ind.

1:30 pm—Patternmaking.

Epoxy Resins—A Practical Tool for the Patternmaker, Allen Cooper, Furane Plastics, Inc., Los Angeles.

3:30 pm—Equipment Meeting.

Pressure Molding — W. L. Adams, Eastern Clay Products Dept., International Minerals & Chemical Co., Skokie, Ill.

Sand Reclamation and Conveying — R. L. McIlvaine, National Engineering Co., Chicago.

4:30 pm—Closing remarks by General Conference Chairman E. G. Gaskell and Southern California Chapter Chairman O. H. Rosentretter.

5:30 pm—Fellowship Hour.

Prof. Barker Retires

■ Prof. George J. Barker, one of Wisconsin's pioneers in the promotion of cooperation between industry, engineering and research has retired after 37 years with the University of Wisconsin. Beyond his teaching and research duties, he devoted much of his time to industry-education activities, serving on as many as six AFS committees at one time.

In 1950 Barker was Chairman of the AFS Education Division and in 1953 was awarded an AFS Honorary Life Membership in recognition of . . . "outstanding contributions to the Society and the castings industry, in addition to the education of young engineers." Barker served as Chairman of the AFS Wisconsin Chapter 1956-57.

He was one of the founders of the Foundry Educational Foundation which annually provides scholarships to outstanding engineering students.

Prof. Barker embarked on his teaching career in a country school in North Dakota. During his first summer he served as a stake boy with a surveying party on a railroad location that so stimulated his interest in engineering that he promptly entered the College of Engineering at the University of Wisconsin. He received a B.S. and an M.E., the latter in Mining and Metallurgy.

Until 1921 he was employed in the chemical and mining industries and returned to the University of Wisconsin as an instructor in mining and metallurgy. He later advanced to assistant professor, professor and chairman of the department.

It was during his term as departmental head that the University of Wisconsin made rapid strides in the field of foundry education.

national news

Modern Foundry Technology Adapted to Southwest is Theme of Regional

■ Modern technology adapted to southwestern foundry operations will be the theme of the Texas Regional Conference to be held March 19-20 at the Menger Hotel, San Antonio, Texas.

The conference is sponsored by the AFS Texas Chapter with C. R. McGrail, Alamo Iron Works, San Antonio, Texas, serving as general conference chairman. Program co-chairmen are Elmore C. Brown, Whiting Corp., Houston, Texas and Edwin E. Pollard, Western Foundry Co., Tyler, Texas.

A Texas barbecue and entertainment will be held on Thursday evening and a banquet will be held Friday evening. In addition to the technical program a two-day ladies program has been arranged.

THURSDAY, MARCH 19

8:00 am—Registration.

10:00 am—General Meeting.
Shell Cores—Herbert von Wolf, Shalco Engineering Corp., Palo Alto, Calif.
Which Core Process—Anton Dorfmueller, Jr., Archer-Daniels-Midland Co., Cleveland.

12:30 pm—Luncheon; Speaker, AFS President L. H. Durdin.

2:00 pm—Steel Session.
Dry Air vs. Oxygen for Carbon Reduction, John Bridges, Cameron Iron Works, Houston, Texas.

2:00 pm—Non-Ferrous Session.
Aluminum Casting Quality Control, D. L. LaVelle, American Smelting & Refining Co., South Plainfield, N. J.

2:00 pm—Gray Iron Session.
Developments on Cupola Design and Operation, R. A. Clark, Electro Metallurgical Co., Div. Union Carbide Corp., Cleveland.

3:40 pm—General Meeting.
Pattern Engineering, P. B. Croom, Houston Pattern Works, Houston, Texas.

7:00 pm—Texas Barbecue and Entertainment.

FRIDAY, MARCH 20

9:00 am—General Meeting.
Self Hardening Binders, O. J. Myers, Reichhold Chemicals, Inc., White Plains, N. Y.
Carbon Mold Materials, Day E. Cutler, J. S. McCormick Co., Pittsburgh, Pa.
Modern Concepts of Refractory Coatings, Gordon W. Gottschalk, Thiem Products, Inc., Milwaukee.

12:30 pm—Steel Round-Table Luncheon.
Heat Treatment of Steel Castings, Charles F. Lewis, Cook Heat Treating Co. of Texas, Houston, Texas.
Steel Melting for Castings, L. J. Venne, Electro Metallurgical Co., Union Carbide Corp., Cleveland.

12:30 pm—Non-Ferrous Round-Table Luncheon.
Aluminum Melting & Pouring Practice, T. E. Kramer, American Alloys Corp., Kansas City, Mo.
Brass & Bronze Melting Practice, Edward Mooney, Benj. Harris & Co., Chicago Heights, Ill.

12:30 pm—Gray Iron Round-Table Luncheon.
Cupola Refractories, T. E. Barlow, Eastern Clay Products Dept., International Minerals & Chemical Corp., Skokie, Ill.
Gray Iron Metallurgy, V. H. Patterson, Vanadium Corp. of America, Chicago.

3:40 pm—Steel Session.
C Process, Dale W. Davis, Oklahoma Steel Castings, Inc., Tulsa, Okla.

3:40 pm—Non-Ferrous Session.
Brass & Bronze Casting Quality Control, Ray Cochran, R. Lavin & Sons, Chicago.

3:40 pm—Gray Iron Session.
Gating & Risering, David Matter, Ohio Ferro-Alloys Corp., Canton, Ohio.

7:15 pm—Banquet; Speaker, Dr. Harold Vagtborg, Southwest Research Institute, San Antonio, Texas.

LADIES PROGRAM

Thursday, March 19

Morning— Registration.
Noon— Luncheon and Style Show.
Afternoon— Poolside Tea and Swim.
Evening—
Texas Barbecue and Entertainment.

Friday, March 20

Noon— River Cruise and Luncheon.
Afternoon— Tour of San Antonio.
Evening— Banquet.

Elect Hodgson and DeRoss as Officers of Committee

■ George Hodgson, National Lead Co., Doehler Jarvis Div., Toledo, has been elected Vice-Chairman of the Die Casting and Permanent Mold Division Research Committee. A. B. DeRoss, Kaiser Aluminum & Chemical Sales, Inc., Chicago, has been elected Secretary.

It's Your Business

They're Happy at the Foundry

by DEVON SMITH/

Financial Editor, The Toronto Telegram

■ *"They're happy at the foundry," says Devon Smith, financial editor for the "Toronto Telegram." Smith who writes the Its' Your Business column in the "Telegram", based his Nov.,* 19, 1958 *column on the AFS Publication* THE FOUNDRY IS A GOOD PLACE TO WORK. *His column reads as follows:*

The foundry is a good place to work.

The American Foundrymen's Society says so; who should know better?

They've put out an illustrated booklet to prove the point. After reading the thing you begin to wonder why you've wasted your life getting to be something else other than a foundryman.

"Men and metals make an industry," AFS claims, talking proudly about such things as "the creating of useful tools from the resources of the soil itself—ores, water, sand and clay."

Every product begins in the foundry, they point out. Even food and clothing depend heavily upon devices which in turn depend on the foundry for their existence.

And the booklet shows how castings are made, and why they're made that way.

It goes into the patternmaking, molding, coremaking (cores shape the inside of a casting), melting and finishing. There is also a bit on product control and heat treating.

The whole purpose of the booklet appears to be to convince people that the foundry is a good place to work, a place a man can be proud and satisfied to work.

It's a very proud trade, the foundryman's.

But any line of endeavor which survives in a competitive world has reason to be proud. It serves society well or it could not continue to exist.

So any industry, trade or service could follow the foundrymen's lead and create a valuable element of pride in its own ranks.

T&RI Emphasizes Metals, Design

■ Preparation and melting of metals and principles of gating and risering for castings will be heavily emphasized in the next six courses presented by the AFS Training & Research Institute.

Included in March, May and July will be the metallography of both ferrous and non-ferrous metals, metallurgy and cupola melting of gray iron, melting of copper-base alloys and gating and risering of castings.

Recent additions to the T&RI schedule are two west coast courses in *Gating and Risering of Castings*. Both will be co-sponsored with California Chapters. The Southern California Chapter will co-sponsor the course April 24-25 at the Rodger Young Auditorium in Los Angeles. The Northern California Chapter will co-sponsor the course April 27-28 at the Claremont Hotel, Berkeley, Calif. This is the second course co-sponsored by the Northern California Chapter. In 1958 it presented *Cupola Melting of Iron*.

May 4-5, the Ontario Chapter will co-sponsor its second T&RI course with the presentation of *Melting of Copper-Base Alloys*. In 1958 it co-sponsored the *Cupola Melting of Iron*.

Within the first three months of its 1959 schedule, T&RI will have presented courses in Chicago, Birmingham, Ala., Los Angeles, Berkeley, Calif. and Hamilton, Ont. The broadening scope of its activities is indicated by its co-sponsoring of courses with four chapters.

Course Change

The Cupola Melting of Iron course, originally scheduled for Feb. 2-6 in Chicago, has been rescheduled for May 11-15 at the Hamilton Hotel in Chicago.

In an effort to present the most thorough coverage of material in the time alloted, the latest teaching methods are used. These include visual aids, discussion periods, operating problems, laboratory work, achievement tests, technical talks and question and answer periods.

AFS publications and other text books are used as well as the most recent research literature.

Achievement tests are given at the conclusion of the courses followed by a discussion period. Results are made available both to the student and his employer.

1959 T&RI Courses

March-July

Subject and Description — *Dates*

Metallography of Ferrous Metals ..... **Mar. 9-11**
Demonstration and work shop course for melters, supervisors, foremen, foundry engineers, researchers, laboratory technicians, metallurgists and design engineers. Basic metallurgy, terminology, phase diagrams, micro and macro analysis, physical properties based on metallographic interpretation and heat treatment are studied. One day of the course is spent on demonstrations and workshop activities in the laboratory. Metal specimens are prepared and analyzed. Course MTY1A, $80, Chicago.

Gating & Risering of Castings ..... **April 24-25**
Instruction course covering theory and practice on the various problems relating to gating and risering. Metal flow, solidification phenomena, heat transfer, shrinkage, hot tears, ferro-static pressure, gate and riser design, mold wall movement, and surface tension are some of the many facets covered. Intended for foremen, technicians, foundry engineers, supervisors, industrial engineers and production and quality control personnel. Course to be presented in Los Angeles; fee, $45.

Gating & Risering of Castings ..... **April 27-28.**
Above course to be presented at Berkeley, Calif. Fee, $45.

Melting of Copper-Base Alloys ..... **May 4-5**
Course of instruction for melters supervisors, metallurgists and foremen. Nomenclature, alloy classification, melting fundamentals, equipment, controls, testing and raw materials. Basic control variables are considered in light of optimum results. Course M2A, $45, Hamilton, Ont.

Cupola Melting of Iron ..... **May 11-15**
Instructional course for cupola operators, supervisors, metallurgists and foremen. Basic principles for efficient cupola operation are studied with emphasis on cost reduction. Raw materials, cupola design, combustion control, metallurgy of cast iron, maintenance and new developments. Course M3A, $90, Chicago.

Metallurgy of Gray Iron ..... **May 25-27**
Intensive instruction on the basic metallurgy of gray iron. Metal compositions, alloys, physical and mechanical properties. Photo-micrographic examples are shown with the interpretation of microstructures. Controlling mechanical properties. For melters, metallurgists, engineers, researchers, supervisors and management. Course MET1A, $60, Chicago.

Metallography of Non-Ferrous Metals ..... **July 13-15**
Demonstration and work shop course for melters, supervisors, foremen, foundry engineers, researchers, laboratory technicians, metallurgists and design engineers. Basic metallurgy, terminology, phase diagrams, micro and macro analysis, mechanical properties based on metallographic interpretation and heat treatment are studied. One day on demonstrations and workshop activities in the laboratory. Metal specimens are prepared and studied. Course MTY2A, $80, Chicago.

national news

Three Investigations Into Density of Sand

■ Three investigations into sand density are being made by the Sand Division Basic Concepts Committee. These are: methods for compaction; angularity; and possibility of using glass spheres for observation.

■ In the study of dry density, compaction tests will be made using a 100 cc volumetric flask with compaction accomplished by tamping the side of the flask while it is being rotated until constant volume has been obtained. Additional tests will be made using tamping versus vibrating in an effort to develop a standard compaction method which will yield repetitive results.

■ Following a review of new data it was agreed that three sands will be checked for angularity using the Hoffman method.

■ Investigation will be made regarding the use of glass spheres in the problem of packing to provide a base line of comparison for various types of sand. Preliminary tests will be made on density using 100 gr samples of glass beads with a fineness of 40, 70, 100 and 200.

Heat Transfer Group to Start Project in Foundry

■ Preliminary experiments in the foundry have been recommended by the Heat Transfer Committee prior to the sponsoring of a research project dealing with the heat transfer problem in castings.

Research will be conducted in several shapes of runners with thermocouples in strategic locations to measure the temperature drop as the metal progresses down the runner at various distances.

Four types of runners will be considered; rectangular, cylindrical, trapezoidal (essentially square) and a tall narrow runner. The rectangular runners will have a 1:3 dimensional ratio with preliminary work conducted on a runner ½ x 1½ in., and the other shaped runners so dimensioned that the hydraulic diameter remains the same.

Aluminum May Be Cause of Snotters in Steel

■ Snotter defects in steel castings may originate from the aluminum used in the deoxidation process. However, all defects may not originate from the same source, since some may originate from the furnace slag.

These indications were reported in a review of results on the investigation of the snotter problems in steel castings being conducted at Michigan University under sponsorship of the Steel Division.

Following the preliminary deoxidation, it was decided to continue the research at the university by studying:

■ Possibility of using modified deoxidizers.

■ Study the effect of casting section size which influences the snotter defect by casting a light plate and a heavy ball pattern.

Spain to be Host to International Oct. 4-10

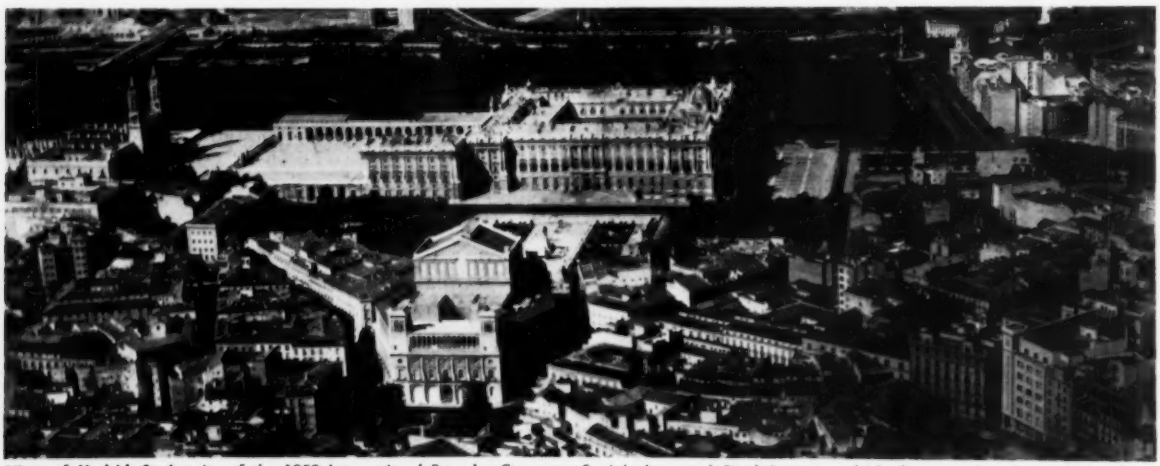
■ Technical papers, meetings of International Committees, official receptions, plant visitations, social functions, special programs for the ladies and post-congress tours are included in the program for the 26th International Foundry Congress.

Arrangements for the Congress to be held Oct. 4-10 in Madrid, Spain, under the sponsorship of the International Committee of Foundry Technical Associations, are being made by Spain's Institute of Iron and Steel. The Institute conducts technical activities for the iron and steel industry. A feature of the International will be the opening of the Institute's new facilities at University City.

Spain has a history in producing and working metals dating back beyond the first century. It has been famous for its handicrafts; its high-quality ore beds capable of producing soft iron and even steels by the direct process; and the Catalan forge.

At the start of the 20th century, Spain's steel production was only 166,000 tons, increasing to 1,022,000 tons in 1929. This figure was not reached again until 1954 and has been steadily increasing.

In 1957, 1,300,000 metric tons of steel were produced with 3,000,000 metric tons predicted for 1960 and 4,500,000 metric tons forecast for 1965.



View of Madrid, Spain, site of the 1959 International Foundry Congress. Spain's Iron and Steel Institute which directs technical activities of the iron and steel industry, is organizing the 26th International, sponsored by the International Committee of Foundry Technical Associations.

chapter news

Approximately 100 members at the **New England** January meeting heard J. Coggin, Elmira foundries, General Electric Co., speak on *Recent Observations in European Foundries.* Shown are Chapter Director **Phillip C. Smith,** also of General Electric, and speaker **Coggin.** *—J .H. Orrok & F. S. Holway*

Non-destructive testing panel at January meeting of **Wisconsin** Chapter included **Dr. Arthur Barkow,** Marquette University; **Clarence Karrer,** Crucible Steel Casting Co.; **Bruce Norris,** Allis-Chalmers Mfg. Co.; and **Henry Seeboth,** Larpen Industries. *—Bob DeBroux*

George Pfaff, Wheelabrator Corp., Mishawaka, Ind., addressing January meeting of **Michiana** Chapter.

Central New York Chapter's first annual Ladies Night. Bud vases on tables were given to ladies.

Fred Riddell, H. Kramer & Co., Chicago, speaker at **Michiana** Chapter January meeting.

St. Louis Chapter

Fundamentals of Refractories

■ Approximately 100 foundrymen attended the January meeting. R. A. Witschey, A. P. Green Fire Brick Co., Mexico, Mo. was the speaker for the evening. *—R. E. Hard*

Piedmont Chapter

Mechanization in Small Foundry

■ An illustrated lecture on mechanization in small foundries was given at the January meeting held in Greensville, N. C., by C. V. Nass, Beardsley & Piper Div., Pettibone Mulliken Corp., Chicago. Various pieces of mechanized equipment which could be used in any size foundry were explained.

—H. R. Fisher

Northern California

Hears Discussion on Sands

■ How to select the correct sand for various castings was discussed at the January meeting by C. A. Sanders, American Colloid Co., Skokie, Ill.

Chapter President Gordon L. Martin, Atlas Foundry & Mfg. Co., Richmond, Calif., served as presiding officer. Vice-President Donald C. Caudron, Pacific Brass Foundry of San Francisco, San Francisco, served as technical chairman. *—E. J. Ritelli*

Central Indiana Chapter

What's New in Foundry Sands

■ A panel discussion on *What's New in Foundry Sands* was held in January despite the worst weather in years. Paul Faulk, Electric Steel Castings Co., Indianapolis, acted as moderator.

Panelists were: K. A. Miericke, Baroid Div., National Lead Co., Chicago; E. E. Wene, Link-Belt Co., Indianapolis; and C. M. Eberhardt, Central Foundry Div., GMC, Danville, Ill. *—William R. Patrick*

Name Purdue Chairmen

■ Dallas Lunsford, Perfect Circle Co., Hagerstown, Ind., has been named general chairman of the 1959 Purdue Metals Castings Conference to be held Oct. 29-30 at Purdue University, Lafayette, Ind. Howard Vorhees, manufacturers agent, Mishawaka, Ind., will be the conference program chairman. The meeting will be held in the Memorial Center.

chapter news

Northeastern Ohio Chapter Chairman **Emil J. Romans,** National Malleable & Steel Castings Co., addresses January meeting. Others are speaker **E. J. Mapes,** Pickands, Mather & Co.; Secretary **Howard E. Heyl,** Archer-Daniels-Midland Co.; **James B. Babcock,** Pickands, Mather & Co.; 1st Vice-President **Al Hinton,** Aluminum Co. of America; 2d Vice-Chairman **Norman J. Stickney,** Sand Products Co.; Membership Chairman **Henry Apthorp,** East Ohio Gas Co.; Director **John F. Wallace,** Case Institute of Technology. *—Harold Wheeler*

Dr. L. Pigeon, professor of metallurgy, University of Toronto and **Dr. R. Petch,** associate professor of metallurgy, McMaster University, are shown shaking hands at the **Ontario Chapter** January meeting. Standing with the professors are metallurgy students from both universities. Also with group is **Ted Tafel,** Ontario Chapter Vice-President, American Standard Products (Canada) Ltd., Toronto, Ont. *—David Magder*

New England Chapter Chairman **William N. Ohlson** (second from left) shakes hands with AFS General Manager **Wm. W. Maloney** at the January meeting. On the extreme left is AFS Secretary **Ashley B. Sinnett** and on right is AFS Regional Vice-President **Henry G. Stenberg.**

Wisconsin Chapter

Non-Destructive Testing Panel

■ Betatron, x-ray, die penetrant and gamma ray testing were discussed at the January meeting by a three-man panel with Dr. Arthur Barkow, serving as moderator.

Bruce Norris, Allis-Chalmers Mfg. Co., discussed die penetrant inspection, ultrasonic inspection and radiography of heavy sections through the use of the betatron. Die penetrant is a method of surface inspection for the average plant. Surface imperfections will be shown which may require a more thorough inspection with other sources such as x-ray. The Allis-Chalmers 24-million volt betatron used for inspecting atomic energy castings was described.

Clarence Karrer, Crucible Steel Casting Co., presented an illustrated talk on the utilization of radiography through the use of x-rays and radioactive materials. Internal casting defects and weaknesses revealed by these methods may be corrected through redesign.

Henry Seeboth, Larpen Industries, discussed the use of various sources of energy such as x-rays, gamma rays and radioactive cobalt in commercial applications. Much of the equipment discussed was of the portable or semi-portable type allowing equipment to be taken to the castings.

The program was arranged by the general program committee headed by L. J. Andres in cooperation with the Milwaukee section of the Society for Nondestructive Testing.

—Erich Sobota

Philadelphia Chapter

Observes Past Chairmen's Night

■ *Factors Influencing Gating and Risering Practice* were explained at the January meeting by Robert B. Fischer, Ingersoll-Rand Co., Phillipsburg, N. J.

Ten former chairmen attended the chapter's first Past Chairmen's Night. They were: H. C. Winte (1957-58); W. S. Giele (1956-57); C. W. Mooney, Jr. (1955-56); D. E. Best (1954-55); G. H. Bradshaw (1951-52); C. B. Jenni (1950-51); W. A. Morley (1949-50); E. C. Troy (1947-48); R. Latham (1944-45); R. J. Keeley (1940-41). *—E. C. Klank*

Utah Chapter

Reducing Foundry Scrap

■ Clyde Sanders, American Colloid Co., Skokie, Ill., discussed *Does This Scrap Occur in Your Foundry* at the January meeting held in Provo, Utah.

—S. J. Beeley

Rochester Chapter

Use of Plastics in Patterns

■ Plastic patterns and foundry equipment were discussed at the January meeting by Donald Wolcott and Richard Park of Houghton Laboratories, Olean, N. Y. The speakers, substituting for J. F. Roth of Cleveland who was ill, outlined practical applications for epoxy resins and the advantages in pattern equipment.

—Thomas B. DeStefani

Central Illinois Chapter

Has Talks on Shell Cores

■ J. E. Stock, John Deere Waterloo Tractor Works, Waterloo, Iowa, and M. H. Horton, Deere & Co., Moline, Ill., discussed the principles of shell cores at the January meeting. Subjects covered included sand mixing, types of equipment and problems and solutions. The speakers emphasized that although the process has a great many advantages that it is not a cure-all for foundry problems.

—Paul McCrea

Birmingham Chapter Vice-Chairman **J. R. Cardwell,** Stockham Valves & Fittings, Inc., (left) and Chapter Chairman **M. D. Neptune,** James B. Clow & Sons, (right) flank speaker **J. S. Vanick,** International Nickel Co., New York.

Control of foundry noise was outlined at the January meeting of the **Saginaw Valley** Chapter by H. J. Weber, AFS Director of Safety, Hygiene and Air Pollution Control. Shown are: technical chairman **F. P. Strieter,** Dow Chemical Co., Midland, Mich.; **speaker Weber;** Chapter Chairman **Arthur H. Karpicke,** Central Foundry Div., GMC, Saginaw, Mich.

—John R. Fraker

Cincinnati Chapter

Ferrous, Non-Ferrous Sessions

■ Two speakers addressed the January meeting held at the Alms Hotel, Cincinnati.

D. L. LaVelle, Federated Metals Div., American Smelting & Refining Co., South Plainfield, N. J., spoke on *Aluminum Foundry Practices.* He reviewed the principal causes of aluminum casting defects and methods for correction.

Prof. J. F. Wallace, Case Institute of Technology, Cleveland, spoke on *Gating Gray Iron Castings,* explaining theoretical gating requirements and their application in the commercial field. *—J. D. Claffey*

How Others Are Doing It

Chairman Resignation

Northern Illinois & Southern Wisconsin Chapter appointed two past-chairmen to fill the vacancy created when Chapter Chairman Harry V. Rossi was transferred out of town.

Now serving as co-chairmen are: Richard A. Oster, The Vocational and Adult School, Beloit, Wis., and Milton Bacon, Beloit Foundry Co., Beloit, Wis.

This plan does not disrupt the terms of other chapter officers and takes advantages of the past experience of former chairmen.

Birmingham Chapter

Role of Foundry Research

■ The value of research to management in the development of new and improved castings to meeting competition from other methods of fabrication was outlined at the January meeting by J. S. Vanick, International Nickel Co., New York.

Research, he said, will also insure a continued growth of the castings industry. The January meeting was the chapter's annual management night. *—W. A. Quenelle*

Why Identification Badges?

■ Reasons for use of identification badges include: aids new members in becoming acquainted; some members need a point of interest to start a conversation; assists in group identification when meetings are held in public places.

Central New York Chapter

Report on European Tour

■ How the CO_2 process is used in Europe was discussed at the January meeting by Emil A. Piper, Pohlman Foundry Co., Buffalo, N. Y.

He reported that blows in the use of CO_2 gas were caused by excessive moisture from the sodium silicate binder. The blows can be minimized by drying the cores with a gas torch.

Other observations:

- Restricted mulling time and use of sand within two hours of preparation is beneficial.
- Patterns from European customers are in better condition than those received by foundries in this country.
- Castings must be cold before shakeout.

Piper, who visited numerous foundries on a European tour, illustrated his talk with slides of European shops and practices. *—C. W. Diehl*

Holds Simultaneous Sessions

Michiana Chapter

■ Simultaneous ferrous and non-ferrous sessions were held at the January meeting. George Pfaff, Wheelabrator Corp., Mishawaka, Ind., pointed out that attention to blast cleaning equipment at regular intervals will result in lower cost. What and when to check was outlined by the speaker who also discussed steel shot and dust collector efficiency.

Fred Riddell, H. Kramer & Co., Chicago, explained how to make better copper-base castings. Chief causes for scrap castings are accounted for by poor supervision, gassy metal, poor gating and incorrect pouring. Recent developments in vacuum melting and vacuum ladle degassing were also discussed. *—Walt Ostrowski*

British Columbia Chapter

Improving Casting Quality

■ Factors to be considered to obtain maximum sand performance and casting quality were enumerated at the January meeting by Clyde A. Sanders, American Colloid Co., Skokie, Ill.

He emphasized the importance of wider grain size distributions and the matter of surface area rather than fineness numbers. He suggested that foundries check the bentonite from suppliers to see that the correct type is being received since hot compression strength as well as green strength are important.

—A. W. Greenius

chapter news

Shown at **Central New York** Chapter's Christmas party. Seated: **Mrs. Donald Kinney, Mrs. Peter Lampreda** and **Mrs. William LaPorte** (back to camera.). Standing: **Donald Kinney,** Prosperity Co.; **Paul Eddy,** Continental Can Co.; and **Peter Lampreda,** Waldwell & Ward Brass Co. —*C. W. Diehl*

How Others Are Doing It

Attendance

Chapters attending the Region 6 administration meeting reported that general interest meetings drew the largest audiences.

In Region 6, chapters find that Friday night attracts the largest audiences, due primarily to distances traveled. Some chapters report that attendance is as much as 50 per cent greater on Friday nights.

Central Michigan Chapter

Survey Before Installation

■ Foundrymen were warned that a study of basic problems must be made before installation of equipment for ventilation systems and control of noise and radiant heat. H. J. Weber, AFS Director of Safety, Hygiene and Air Pollution enumerated examples of how money was wasted on new equipment because only superficial studies were made of the problems involved.

Weber at the January meeting recommended that foundrymen make better use of existing literature in order to obtain satisfactory results.

J. M. Schappert, (third from left) Campbell, Wyant & Cannon Foundry Co., Muskegon, Mich., speaker at Western Michigan January meeting talks to **Frank Cheever,** Campbell, Wyant & Cannon Foundry Co., Chapter Secretary **C. H. Cousineau,** Carpenter Bros, Inc., North Muskegon, Mich.; Director **James Vander Meulen,** American Seating Co., Grand Rapids, Mich. —*Dan Connell*

Tennessee Chapter members at the January meeting heard C. E. Sutton, Jr., General Electric Co., speak on *Productive Maintenance—59.* Left to right are Chapter Chairman **W. L. Austin,** U. S. Pipe & Foundry Co., Chattannooga, Tenn.; speaker **Sutton;** Chapter Vice-Chairman **Charles E. Seman,** Crane Co., Chattanooga, Tenn. —*H. G. Nelson*

Eastern New York Chapter

Five Ways to Make Profit

■ Five ways to make a profit in the foundry industry were presented at the January meeting by A. B. Steck, Metallurgical Associates, Inc., New York. The suggested methods were: better selling techniques, reconversion to new casting processes, raising prices, lowering the amount of rejects and improving operating procedures.

Among the techniques covered were:

- Use of coated copper tubing in intricate coring of wave guides.
- Use of a double investment and limestone in shell molding for improving surfaces on low carbon steels.
- Precision shell process which eliminates many steps used in investment casting but yielding physical properties of 200,000-250,000 psi and 5 to 10 per cent ductility.

—*Leonard C. Johnson*

Metropolitan Chapter

New Approach to Casting Design

■ "Our industry can not only recapture some of the lost business but expand its own real considerably," Hans J. Heine, Malleable Founders Society, told the January audience.

Heine suggested a new approach to the problem of casting design, less reliance on theoretical formulae and greater use of tools and information available to designers. He illustrated his point with 11 steps which could be used for an analysis for any difficulty traceable to casting design.

—*C. H. Fetzer*

Central Illinois chapter held its annual Christmas Party and Ladies Night in Peoria. More than 400 persons attended including Mr. and Mrs. **Sieboe Reents** (photo). —*Paul McCrea*

Western Michigan

Role of Foreman in Foundries

■ Industry has never been constant with foremanship—either too much training or none at all, J. M. Schappert, Campbell, Wyant & Cannon Foundry Co., Muskegon, Mich., told chapter members at the January meeting.

Schappert told how the word "foreman" originated in guilds about 1000 years ago. Then, as now, he was one chosen to stand in the fore of men in dealing with the owner. Effective supervision is obtained by careful selection plus adequate instruction and training before and after an employee is asked to take over supervisory responsibility and authority. As the foreman is good or bad, so is the company and its labor relations. —*Dan Connell*

Central Ohio Chapter

Holds Annual Winter Party

■ Chapter members held their annual winter party in January at the Lincoln Lodge near Columbus, Ohio. The program included dinner and dancing. John Dusthimer, Keener Sand & Clay Co., Columbus, Ohio, was the party chairman.

—*Joseph A. Riley, Jr.*

Student Chapters Act as Link with Foundry Industry

■ Student Chapters were established as part of the Society's educational program in 1947. Their activities are closely tied in with the educational work of regular committees.

Currently there are 12 Student Chapters located at engineering schools and colleges throughout the country. Many receive help from regular chapters in the form of scholarships or student aid funds or assistance in obtaining equipment.

Other chapter activities in aiding students consist of regular inspection and advisory visits by the Education Committee, furnishing libraries with foundry literature, acting in an advisory capacity for improvement of curricula, assisting the school to obtain better foundry teaching facilities, arranging talks by outstanding foundry leaders, arranging plant tours, and assisting students in obtaining summer work.

Each Student Chapter has a faculty advisor and an industrial advisor. When Student Chapters are located in regular chapter areas the industrial advisor is elected by the board of directors of that chapter.

University of Alabama

Chairman—David Bowers.
Vice-Chairman—Louis Gaynor.
Secretary-Treasurer—William House.
Faculty Advisor—Prof. W. C. Jeffery, University of Alabama.
Industrial Advisor—L. H. Durdin, Dixie Bronze Co., Birmingham, Ala.

Brooklyn Polytechnic Institute

Chairman—Alvin Engelhardt.
Vice-Chairman—Thomas Zmach.
Secretary—Carl Gatto.
Faculty Advisor—Dr. W. H. Ruten, Brooklyn Polytechnic Institute.
Industrial Advisor—C. D. Preusch, Crucible Steel Co. of America, Harrison, N.J.

University of Illinois

Chairman—Richard Bolin.
Vice-Chairman—James R. Strode.
Secretary—Gerald Jones.
Treasurer—Jim Liautaud.
Faculty Advisor—Prof. J. L. Leach, University of Illinois.
Industrial Advisor—John Wagner, Wagner Castings Co., Decatur, Ill.

Massachusetts Institute of Technology

Chairman—W. Scott Latimer.
Vice-Chairman—Barrie Shabel.
Secretary—Harold Brody.
Treasurer—Stephen Goodman.
Faculty Advisors—Prof. H. F. Taylor, Prof. J. F. Elliot and Prof. David Thomas, Massachusetts Institute of Technology.
Industrial Advisors—Herbert H. Klein, Klein-Farris Co., Boston; William Collins, United-Carr Fastener Corp., Cambridge, Mass.

Michigan State University

Chairman—George Shufelt.
Vice-Chairman—Donald Wolfrum.
Secretary—Frederick Slovinski.
Treasurer—John C. Bierlein.
Faculty Advisor—Prof. C. C. Sigerfoos, Michigan State University.
Industrial Advisor—Kenneth Priestly, Vassar Electroloy Products, Vassar, Mich.

University of Michigan

Chairman—Ronald K. Bowen.
Vice-Chairman—Otto K. Riegger.
Secretary-Treasurer—Neil Markva.
Faculty Advisor—Dr. R. A. Flinn, University of Michigan.
Industrial Advisor—Fred J. Walls, Engineering Castings, Inc., Marshall, Mich.

Missouri School of Mines

Chairman—Jerome L. Range.
Vice-Chairman—Buddie R. Smith.
Secretary-Treasurer—Milton Tilman.
Faculty Advisor—Prof. R. V. Wolf, Missouri School of Mines.
Industrial Advisor—R. H. Jacoby, St. Louis Coke & Foundry Supply Co., St. Louis.

Ohio State University

Chairman—Richard C. Zelle.
Secretary—Carl Vessel.
Treasurer—Charles E. Ginn.
Faculty Advisor—Dr. D. C. Williams, Ohio State University.
Industrial Advisor—D. M. Marsh, Cooper-Bessemer Co., Mt. Vernon, Ohio.

Oregon State College

Chairman—Charles F. Query.
Vice-Chairman—Si. L. Arata.
Secretary—Dee J. Hillberry.
Treasurer—Donald W. Dauterman.
Faculty Advisor—Prof. L. M. Frazier, Oregon State College.
Industrial Advisor—J. W. Smith, Oregon Metallurgical Corp., Albany, Ore.

Pennsylvania State University

Chairman—Dan Preska.
Vice-Chairman—Kurt Zippe.
Corresponding Secretary—Myron Carpenter.
Recording Secretary—Tom Derr.
Treasurer—W. P. Winter, Prof., Pennsylvania State University.
Faculty Advisors—A. B. Draper and W. P. Winter, Pennsylvania State University.
Industrial Advisor—I. W. Sharp, American Steel Foundries, Verona, Pa.

Texas A & M College

Chairman—James E. Freytag.
Vice-Chairman—Bennie Edmondson.
Secretary—Joseph L. Cox.
Treasurer—Larry Weber.
Faculty Advisors—Prof. E. D. Kranz and S. E. Brown, Texas A & M College.
Industrial Advisors—R. H. Glenney, Alamo Iron Works, San Antonio, Texas.

University of Wisconsin

Chairman—James R. Widmoyer.
Vice-Chairman—Andrew Millunzi.
Secretary-Treasurer—William S. Irvine.
Faculty Advisor—Prof. Richard W. Heine, University of Wisconsin.
Industrial Advisor—Norman Amrhein, Federal Malleable Co., West Allis, Wis.

Chapters Produce National Officers

■ Participation in local chapter affairs often leads to recognition at the national level. Two AFS Presidents, 16 National Directors and four Medalists were Chapter Officers 10 years ago.

Chapter officers and their affiliations who have obtained national honors are:

Birmingham—Dr. J. T. MacKenzie, Whiting Medalist 1937, Director 1951-1954.

British Columbia—Herbert Heaton, Director 1956-1959.

Central Illinois—Frank W. Shipley, Director 1950-1953, President 1956-57; A. V. Martens, Director 1956-1959.

Central Michigan—C. C. Sigerfoos, Whiting Medalist 1953.

Central New York—Wm. D. Dunn, Director 1957-1960.

Central Ohio—Daniel E. Krause, Whiting Medalist 1953.

Chesapeake—A. A. Hochrein, Director 1957-1960.

Chicago—W. D. McMillan, Honorary Life Member 1956, Director 1958-59; Bruce L. Simpson, Director 1946-1949, President 1955-56.

Cincinnati—Walter J. Klayer, Director 1952-1955.

Northeastern Ohio—Walter E. Sicha, McFadden Medalist 1954.

Northern California—John R. Russo, Director 1957-1960.

Ontario—John L. King, Director 1958-59.

Philadelphia—W.A. Morley, Director 1954-1957.

St. Louis—A. L. Hunt, Director 1951-1954.

Tennessee—K. L. Landgrebe, Jr., Director 1957-1960.

Texas—Jake Dee, Director 1958-1961.

Toledo—Gerald R. Rusk, Director 1956-1959.

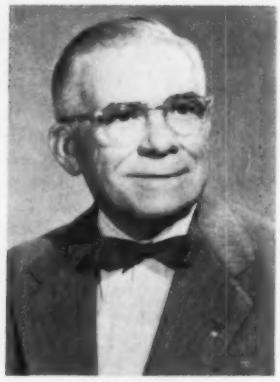
Tri-State—Robert A. Trimble, Director 1955-1958.

Meet More 1958-59 Chapter Chairmen

Emil J. Romans
National Malleable & Steel Castings Co.
Cleveland
Chairman
Northeastern Ohio Chapter

L. B. Polen
Allegheny Ludlum Steel Corp.
Buffalo, N.Y.
Chairman
Western New York Chapter

Cecil N. King
Chrysler Corp.
Detroit
Chairman
Detroit Chapter

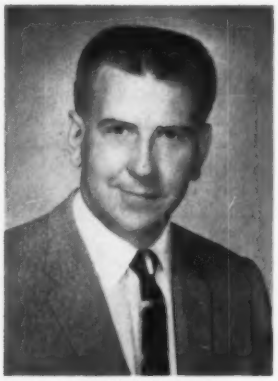


William O. Becker
Atlantic Abrasive Corp.
South Braintree, Mass.
Chairman
Chesapeake Chapter

M. D. Neptune
James B. Clow & Sons
Birmingham, Ala.
Chairman
Birmingham Chapter

Thomas R. Walker, Jr.
U.S. Pipe & Foundry Co.
Burlington, N.J.
Chairman
Philadelphia Chapter

John M. Hughes
Stevenson & Kellogg, Ltd.
Toronto, Ontario
Chairman
Ontario Chapter



David E. Sherman
Engineering Castings, Inc.
Marshall, Mich.
Chairman
Central Michigan Chapter

Edwin F. Peterson
Martin Engineering Co.
Neponset, Ill.
Chairman
Quad City Chapter

Donald G. Schmidt
H. Kramer & Co.
Chicago
Chairman Chicago Chapter

Otto H. Rosentreter
Otto H. Rosentreter Co.
South Gate, Calif.
Chairman
Southern California

Robert E. Mittlestead
Lectromelt Casting Div.
Akron Standard Mold Co.
Barberton, Ohio
Canton Chapter

afs chapter meetings

MARCH

Birmingham District . . March 13 . . University of Alabama, University, Ala. . . *Instrumentation Show.*

British Columbia . . March 20 . . Leon's, Vancouver, B. C. . . H. E. Gould, Washington Iron Works, *"Potential Use of Olivine Sand in the Foundry."*

California Regional Foundry Conference . . March 13-14 . . Huntington-Sheraton Hotel, Pasadena, Calif.

Canton District . . March 5 . . Mergus Restaurant, Canton, Ohio . . United Engineering & Foundry Co., *Plant Visitation.*

Central Illinois . . March 2 . . American Legion Hall, Peoria, Ill. . . W. B. Bishop, Archer-Daniels-Midland Co., *"Which Core Process?"*

Central Indiana . . March 2 . . Athenaeum, Indianapolis . . E. L. Key, Mexico Refractories Co., *"What's New in Foundry Refractories."*

Central Michigan . . March 18 . . Hart Hotel, Battle Creek, Mich.

Central New York . . March 13 . . Drumlins Country Club, Syracuse, N. Y. . . W. J. White, Carver Foundry Products Co., *"CO_2 Cores & Molding."*

Central Ohio . . March 9 . . Shawnee Hotel, Springfield, Ohio . . J. W. Gillespie, Ohio Steel Foundry Co., *"CO_2 Cores."*

Chesapeake . . March 20 . . Park Plaza Hotel, Baltimore, Md. . . *Movies, "New Tools for Industries" and "Mining for Nickel," Courtesy of Rotor Tool Co. and International Nickel Co.*

Chicago . . March 2 . . Chicago Bar Association, Chicago . . *Educational Program, "Production of Foundry Sands."*

Cincinnati District . . March 9 . . Engineers' Club, Dayton, Ohio . . T. W. Seaton, American Silica Sand Co., *"Sand Segregation & Its Problems."*

Connecticut . . *Meeting Replaced by Sand School, Yale University.*

Corn Belt . . March 6 . . Cotner Terrace, Lincoln, Neb. . . *Inland Steel Corp., Film on History of Steelmaking from Ancient to Modern Times.*

Detroit . . March 19 . . Wolverine Hotel, Detroit . . M. Von Braun, Missile Director, Chrysler Corp. *Pattern Exhibit & Contestants' Night.*

Eastern Canada . . March 13 . . Sheraton Mt. Royal Hotel, Montreal, Que. . . R. Sutcliff, Fordath Engineering Co., England, *"British Utilization of Cold-Setting, CO_2 and Shell Techniques."*

Eastern New York . . March 17 . . Panetta's Restaurant, Menands, N.Y.

Metropolitan . . March 2 . . Essex House, Newark, N. J. . . M. Bock, Exomet, Inc., *"How to Improve Casting Quality through Use of Chills, Exothermics & Insulators."*

Michiana . . March 9 . . Club Normandy, Mishawaka, Ind. . . E. H. King, Hill & Griffith Co., *"Quality Control Based on Mold Hardness in the Foundry."*

Mid-South . . March 13 . . Claridge Hotel, Memphis, Tenn.

Mo-Kan . . March 6 . . Fairfax Airport, Kansas City, Kans.

New England . . March 11 . . University Club, Boston . . D. L. LaVelle, Federated Metals Div., American Smelting & Refining Co., *"The Trend for Aluminum Casting."*

Northeastern Ohio . . March 12 . . Tudor Arms Hotel, Cleveland . . J. H. Dunn, Aluminum Co. of America. *Panel, "Designing Castings for Serviceability."*

Northern California . . March 13-14 . . *California Regional Foundry Conference* . . **March 16 . .** Fairmont Hotel, San Francisco . . *Management Dinner* . . **March 20 . .** Mare Island Naval Shipyard, Vallejo, Calif. . . *Visit to Machine Shop, Pattern Shop and Foundry.*

Northwestern Pennsylvania . . March 23 . . Shuster's, Greenville, Pa. . . T. W. Curry, Lynchburg Foundry Co., *"Shop Methods & Control of Ductile Iron Castings."*

Ontario . . March 20 . . Westbury Hotel, Toronto, Ont. . . S. L. Gertsman, Department of Mines & Technical Surveys, *"Penetration—Causes & Cures."*

Oregon . . March 18 . . Heathman Hotel, Portland, Ore. . . W. Aschoff, Oregon Metallurgical Corp., *"Casting Reactive Metals."*

Philadelphia . . March 13 . . Engineers' Club, Philadelphia.

Piedmont . . March 6 . . Virginian Hotel, Lynchburg, Va. . . T. W. Curry, Lynchburg Foundry Co., *"Shop Methods & Control of Ductile Iron Castings."*

Pittsburgh . . March 16 . . Webster Hall Hotel, Pittsburgh, Pa. . . F. W. Less, "Durez Plastics & Chemicals, Inc. *"Coated Sands."*

Quad City . . March 16 . . LeClaire Hotel, Moline, Ill. . . E. E. Braun, Central Foundry Div., GMC, *"A New Approach to Marketing Castings." Management Night.*

Rochester . . March 3 . . Manger Hotel, Rochester, N. Y. . . J. D. Allen, Federated Metals Div., American Smelting & Refining Co., *"New Developments in Non-Ferrous Cast Metals."*

Saginaw Valley . . March 5 . . General Motors Institute, Flint, Mich. . . *Education Night.*

St. Louis District . . March 12 . . Edmond's Restaurant, St. Louis . . J. O'Meara, Banner Iron Works, *Moderator. Round Table Discussion, "Nodular Iron & Its Role in Industry."*

Southern California . . See California *Regional Foundry Conference.*

Tennessee . . March 27 . . Patten Hotel, Chattanooga, Tenn. . . W. M. Ball Jr., R. Lavin & Sons, Inc., *"Human Engineering."*

Texas . . See Texas Regional Foundry *Conference.*

Texas Regional Foundry Conference . . March 19-20 . . Menger Hotel, San Antonio, Texas.

Timberline . . March 9 . . Oxford Hotel, Denver, Colo. . . *National Officers' Night.*

Toledo . . March 4 . . Heatherdowns Country Club, Toledo, Ohio . . R. L. McIlvaine, National Engineering Co., *"Foundry Layouts & Maintenance."*

Tri-State . . March 13 . . Alvin Plaza Hotel, Tulsa, Okla. . . F. Hansen, *"Induction Melting Practices."*

Twin City . . March 10 . . University of Minnesota, Minneapolis . . *Seminar Replaces Regular Meeting.*

Utah . . March 23 . . Grandview Cafe, Provo, Utah . . P. G. Smith, United States Gypsum Co., *"Use of Epoxy Resins for Foundry Work."*

Washington . . March 19 . . Engineers' Club, Seattle . . H. Gould, Washington Iron Works, *"Potential Use of Olivine in Ferrous & Non-Ferrous Foundries."*

Western Michigan . . March 2 . . Bill Stern's, Muskegon, Mich. . . F. Hagquist, Tylene Plastics, Inc., *"Plastic Patterns."*

Western New York . . March 6 . . Sheraton Hotel, Buffalo, N. Y. . . D. E. Krause, Gray Iron Research Institute, *"Research in the Foundry."*

Wisconsin . . March 13 . . Schroeder Hotel, Milwaukee . . *Five Sectional Meetings.*

APRIL

Toledo . . April 1 . . Heatherdowns Country Club, Toledo, Ohio . . J. A. Babcock, Pickands Mather & Co., *"Mining & Smelting of Taconite Ore."*

Saginaw Valley . . April 2 . . Fischer's Hotel, Frankenmuth, Mich. . . E. E. Braun, Central Foundry Div. GMC, *"New Approach to Marketing Castings."*

GM Describes CentraSteel

Continued from page 52

hard, brittle zones. However, the pouring of castings having extremely thin sections throughout, such as automotive rocker arms, has presented a carbide problem and adjustment of inoculants is necessary for such parts.

COMMERCIAL APPLICABILITY

While the material is still in the experimental stage, many types of castings have been made in order to determine the applicability of the material to a wide variation of shapes and sizes. Examples of castings which have been produced experimentally are shown in Fig. 13. Microstructure and mechanical properties obtained from bearing journal sections of an experimental automotive crankshaft casting in both the as-cast and normalized condition, are shown in Fig 14. and 15. Results compare favorably with those obtained from test blocks.

Preliminary machining checks under normal production conditions indicated that, in comparison with pearlitic malleable iron, identical turning speeds and feed rates may be used while drilling speeds must be reduced slightly. Again it is felt that carbon content is a contributor, since the quality of free graphite is somewhat less than in pearlitic malleable.

Attention is drawn to the ability to produce a ferritic matrix by annealing at 1350 F. Therefore, it may be possible, using the CentraSteel base iron, to produce all of the parts currently produced from both ferritic and pearlitic malleable iron. With increased strength obtainable through normalizing and quench and temper treatments in addition to the high elastic modulus, use could be extended to parts presently forged from plain carbon steel such as pinions, gears, shafts, cams, crankshafts and dies.

SUMMARY

Obviously, the most significant feature of CentraSteel is the achievement of obtaining substantially all of the hypereutectoid carbon as free graphite in compacted form with no massive carbide, resulting in high tensile properties and enabling use of the material in the as-cast condition. The high elastic modulus also suggests application to parts for which many of the presently available cast materials would be unacceptable.

In addition to as-cast properties, the range of mechanical properties which can be produced due to heat treatment should be a further advantage, in that numerous types of parts may be produced from the same base composition. Aside from mechanical properties similar to those of cast steel, castability appears to be superior to steel. Feeding characteristics are slightly inferior to white iron. However, experience to date has indicated that sound castings can be produced in most cases with only minor alterations to usual malleable iron gating and risering design.

Some foundry problems still exist which have prevented the release of CentraSteel to production. Further work to overcome these difficulties is presently being carried out at Central Foundry Division and the research laboratories.

CentraSteel, although lacking the ductility of steel, has an elastic modulus very nearly equal to steel, equivalent strength, better machinability and probably lower initial cost per part. CentraSteel, therefore, would make available to the design engineer a material which may very well be considered as a replacement for plain carbon steel forgings while permitting the flexibility of design offered through the use of castings.

ACKNOWLEDGMENTS

The authors wish to acknowledge the valuable assistance rendered by the many individuals at the General Motors Central Foundry Division and Research Laboratories.

In particular the authors wish to thank A. Seling and K. Spray of Central Foundry Division for their cooperation in developing melting and casting techniques for large experimental heats and preparation of various castings.

Recognition is also given to P. R. White, formerly of the Research Laboratories, for his aid in establishing the early approximate composition range.

Important contributions were made by D. J. Henry of the Research Laboratories in supervising the early experimental work. Also, J. C. Denman of the Research Laboratories for assistance with laboratory heats and preparation of the many necessary metallographic specimens.

The Alloy Casting Institute

Continued from page 35

sistant grades of the chromium-predominant types. Most are the familiar 18-8 stainless steels. These are the CF types, which combine fair tensile strength, excellent ductility and good resistance to corrosion by many media. Addition of molybdenum to the alloy (CF-8M and CF-4M) improves resistance to reducing chemicals and to intergranular attack. The columbium containing CF-8C alloy, is used to protect against intergranular corrosion where castings are to be welded without subsequent heat treatment; the extra low carbon grade CF-4 is also used for this purpose.

As temperatures and concentration of corrodents are increased under strongly oxidizing conditions, Group I hardenable alloys cannot be considered. If these conditions become especially severe, the choice narrows down to the alloys of Group II. The CE alloys have good resistance to intergranular attack in the as-cast condition, so they are used where castings can not be heat treated conveniently because of size or configuration. The CH, CK and CF-8M grades are used to resist strong, hot, weakly oxidizing solutions such as sulfurous, sulfuric, acetic, and phosphoric acids. If the conditions are especially severe where these materials are involved, the CN alloys of Group III are specified.

The Group II heat resistant alloys can be used in sulfur-containing, oxidizing and reducing atmospheres. Type HH is one of the most popular in this group—it has good corrosion resistance and good strength at elevated temperatures. Type HE is useful, since it is considerably stronger and more ductile than the straight chromium HC grade. Type HK alloys are also widely specified because they have excellent creep strength coupled with good resistance to hot gas corrosion. Having similar properties to HK, the HL type is specified because of its improved resistance to high sulfur atmospheres.

III. Nickel chromium alloys: Group III contains the nickel-predominant types. The type CN alloys, containing small amounts of molybdenum and copper, are useful in resisting sulfuric acid in a wide range of concentrations and temperatures. They also show good resistance to other reducing chemicals. Among the Group III heat resistant alloys, types HT and HU are most popular. They have good resistance to carburizing atmospheres and are useful for cyclic heating service. The high nickel alloy types HW and HX are used for severe high temperature applications and withstand repeated heating and cooling without cracking. However, the Group III heat resistant alloys are unsuitable for use in the presence of appreciable sulfur.

MODERN CASTINGS MAGAZINE IS YOUR INSIDE TRACK TO THE 63d AFS CASTINGS CONGRESS AND ENGINEERED CASTINGS SHOW

(Chicago, April 13-17, 1959)

BEFORE YOU COME TO THE SHOW

The April OFFICIAL CONVENTION ISSUE will give you information that will help you plan your Convention schedule . . . information such as –

- Schedule of events
- Briefs on Convention personalities and industry leaders
- Preprints of many papers to be given at the Congress
- Preview of new applications, latest machines and materials

MODERN CASTINGS will reach you at your regular mailing address when you have time to study and plan for the coming exhibits and events in Chicago. It will be a reliable guide for you as a foundryman as well as for the thousands of product-design engineers who will be AFS guests at the Show.

AFTER YOU ARE HOME FROM THE SHOW

The May CONVENTION REPORT ISSUE will review what you didn't have time to see completely yourself, reporting in detail the happenings and exhibits of the important five-day meeting that only MODERN CASTINGS' entire staff will have time to cover fully. Among the special features of the issue are –

- Data on the kinds of castings in which buyers show most interest
- Over-all summary of major trends in the metalcastings field
- Reports of latest metalcastings research
- Picture record of the Show

The April and May Convention Issues of MODERN CASTINGS are the greatest single source of reliable technical information . . . industry news . . . and practical working foundry data of the year.

WATCH FOR THESE IMPORTANT ISSUES SO YOU CAN GEAR YOUR THINKING TO THE 1959 UPSWING!

ADVERTISERS –

The entire metalcasting industry will look to the Official AFS Magazine for official news about the AFS Convention. These special-purpose issues are your only opportunity for a direct tie-in to this event. Include these important issues in your advertising schedule at regular rates!

modern castings

AFS TECHNICAL CENTER **DES PLAINES, ILLINOIS**

foundry trade news

CASE INSTITUTE OF TECHNOLOGY . . . *Office of Ordnance Research is supporting fundamental research in the solidification of molten metals for purposes of developing greater strength, ductility and toughness.* A grant in the amount of $11,740 has been awarded to J. F. Wallace, associate professor of metallurgical engineering, for a second years study of "Characteristics of Effective Inoculants and Contaminators for Solidifying Molten Metals." The new grant brings to $24,590 the total amount provided by the ordnance research office for the study of solidification mechanisms. Wallace and a team of three graduate students will determine how and why vibration or the addition of contaminants affect solidification.

NATIONAL ORNAMENTAL IRON MANUFACTURERS ASSOCIATION . . . held a successful 1959 Convention in Atlanta Jan. 8-10. Frank Kozik, Scranton Craftsman, Inc., Scranton, Pa., retained his post as president. Other officers elected were: R. W. Colver, M.O.F., Inc., Danville, Ill., first vice-president; A. H. Jones, Jones Iron Works, Baton Rouge, La., second vice-president; Dominic Taverna, Chestnut Welding & Iron Co., Watertown, Mass., secretary-treasurer. Services of Bob Hairston, Memphis, Tenn., were retained as executive secretary. F. B. Burch was appointed editor in-chief of the newly established trade magazine—The National Ornamental Iron Fabricator. Theme of the Convention was *Learn More, Grow More.* Classes were held in all phases of ornamental iron work, cutting, grinding, layout, painting and sales.

The Business and Defense Services Administration . . . U. S. Department of Commerce announced the enrollment of 46 more members in the National Defense Executive Reserve bringing the roster to 912. The BDSA group, composed of business and professional men, would be called on to stage the operation of an emergency production agency both at regional and national headquarters in event of hostilities involving this country. New members from the foundry field are: L. H. Durdin, Dixie Bronze Co., Birmingham, Ala.; E. A. Short, Mid-Continent Steel Castings Corp., Shreveport, La.; J. L. Hart, United States Pipe & Foundry Co., Burlington, N. J.; W. E. Benninghoff, Ohio Crankshaft Co., Cleveland; W. A. Gluntz, Sr., Gluntz Brass & Aluminum Foundry Co., Cleveland; J. E. Hartshorn, General Refractories Co., Philadelphia; H. E. Collins, Hughes Tool Co., Houston, Texas.

Alloys & Chemicals Mfg. Co. . . . Cleveland, were host recently to three of Ohio's Congressmen—W. E. Minshall, F. P. Bolton and M. A. Feighan. Guided by N. L. Butkin, Alloys president, they toured the plant facilities. Bolton's primary interest in the aluminum smelting firm centered around its potential as a source of future business for the St. Lawrence Seaway, with its accompanying increase in employment for Ohioans. Minshall and Feighan were interested in progress and preparation that the firm is making to meet anticipated increase in demand for aluminum.

Noah Butkin, (left) president, Alloys & Chemical Mfg. Co., describes performance of new Quantometer equipment to **Congressman Michael Feighan.**

Biever Air & Hydraulic Equipment . . . Atlanta, Ga., is now representing Hunt Valve Co., of Salem, Ohio, in the Atlanta territory. Hunt is manufacturer of air and hydraulic control valves.

Beardsley & Piper . . . Div., Pettibone Mulliken Corp., Chicago, recently made extensive and comprehensive changes in their sales and marketing department services. W. A. Hunter has now been appointed manager of engineering functions. Hunter will direct expansion of engineering departments.

Four new divisional managers were appointed to provide improved service with better coverage of all machinery in B & P's rapidly expanding line. George Koren became divisional sales manager in charge of all sand processing and shell processing machinery. George Miller became divisional sales manager in charge of coremaking and molding machinery. He will have direct responsibility for the promotion and sales of Flexibo and San-Blo lines. Hank Rach became divisional sales manager in charge of accessory machinery. Cliff Wenninger was appointed divisional sales manager in charge of reclamation and accessory equipment sales.

H. G. Schlichter, vice-president sales, will retire this month, on completion of 38 years with the firm. Well-known throughout the foundry industry he helped in establishing B & P as one of the largest exclusive manufacturers of foundry machinery in the world. He has shared or been responsible for design and engineering of some of the most successful foundry installations in the United States and Canada.

R. F. Nosek, as director of sales, will enlarge the field sales and agent force.

Glenn Turner has been appointed to the newly-created post of manager of marketing and will be assisted by Lloyd Shanks who will also be responsible for export sales and marketing of small units.

Climax Molybdenum Co. . . . Div. American Metal Climax, Inc., New York, announced molybdenum casting breakthrough by the Bureau of Mines promises to be a major contribution to molybdenum technology. It is too early for assessment of its ultimate commercial evaluation. The firm is cooperating with the Bureau in its experiments. Climax has agreed to supply Bureau of Mines research laboratory in Albany, Ore., with necessary molybdenum raw materials and is sending observers to be present at future experiments.

Gordon Sondraker & Co. . . . Los Angeles, and **Industrial and Foundry Supply Co., Inc.,** Oakland, Cal., have been named two West Coast distributors for American Metallurgical Products Co., Inc., Pittsburgh, Pa.

Continued on page 156

A Lester B. Knight & Associates, Inc. Case History

PRICE GUESSWORK CAN BE ELIMINATED

On an assignment for a nationally known manufacturer, the Knight organization installed a standard cost system, and in doing so also established labor standards, developed a materials control, and organized a standards department. Management now can determine more accurately and control pricing and the cost of any casting. This has placed the company in a much better position to establish realistic selling prices and insure profitable operations.

For consultation on any foundry problem, large or small, call on Lester B. Knight & Associates, Inc.

KNIGHT SERVICES INCLUDE:

Foundry Engineering • Architectural Engineering • Construction Management • Organization Management • Industrial Engineering • Wage Incentives • Cost Control • Standard Costs Flexible Budgeting • Production Control • Modernization • Mechanization • Methods Materials Handling • Automation • Survey of Facilities • Marketing

EVIDENCE OF EXPERIENCE

Lester B. Knight & Associates, Inc.

Management, Industrial and Plant Engineers

Member of the Association of Consulting Management Engineers, Inc.

549 W. Randolph St., Chicago 6, Ill.

917 Fifteenth St., N.W., Washington, D.C.

New York Office—Lester B. Knight & Associates, 375 Fifth Ave., New York City 16

Knight Engineering Establishment (Vaduz), Zurich Branch, Bahnhofstrasse 17, Zurich, Switzerland

Lester B. Knight & Associates, G.M.B.H., Berliner Allee 47, Düsseldorf, Germany

Circle No. 718, Page 167-168

let's get personal

L. G. Probst . . . has been named vice-president and eastern district manager for National Engineering Co., Chicago. He has been with the firm since 1945 serving as assistant sales manager for midwest and southern areas. **W. A. Kellogg,** who supervised the eastern territory, will continue to serve as vice-president and consultant on foundry planning and materials handling.

M. A. Le Thomas . . . managing director of Centre Technique des Industries de la Fonderie, Paris, France, and founder-chairman of Association Nationale de la Recherche Technique has been promoted *Commander of the Legion of Honour*. This award is one of the highest grades in that Order.

Frank Lopez . . . formerly of General Electric, has joined Boston Electro Steel Castings, Inc., Boston, as vice-president. **Frank McCorry** has been made vice-president, plant manager. **Jack Murray** has been made vice-president in charge of production.

D. D. Bowman . . . was promoted to vice-president and general manager, Almont Manufacturing Co., Almont, Mich. He was the former assistant-treasurer and is a member, AFS Saginaw Valley Chapter.

M. A. Horlak . . . is the president and treasurer of the new Cinetronics, Inc., Cleveland. He is a member, AFS Northeastern Ohio Chapter.

V. R. Gerace . . . former secretary-treasurer of American Brass & Iron Foundry, Oakland, Calif., has been elected vice-president and assistant general manager. Other officers are: **Arnold Boscacci,** chairman of the board; **Eugene Boscacci,** president; **A. S. W. Love,** executive vice-president and general manager; **M. R. Matthews,** vice-president and **Mrs. Rita Boscacci,** secretary-treasurer.

C. F. Knuepfer . . . is now a foundry consultant, Dallas, Texas, to foundries in the Texas area. Formerly, he was manager of foundry division of Fort Worth Steel & Machinery Co. He is a member, AFS Texas Chapter.

E. M. Tittman . . . has been elected vice-president and director of American Smelting & Refining Co., New York. In December, Tittman was elected chairman of the board and chief executive officer of Southern Peru Copper Corp., in which Asarco holds a majority interest. He will continue that post in addition to his new duties. He has been with the firm for 29 years and recently returned from a three-year stay in Peru, where he administered SPCC's two billion dollar development program at Toquepala and Ilo.

C. R. Welles . . . has been appointed vice-president of sales of the Hanna Furnace Corp., Merchant Pig Iron Div., National Steel Corp., Detroit. He replaced **William Kerber** who retired.

D. R. Hepler . . . has been appointed vice-president, manufacturing, for Cooper Alloy Corp., Hillside, N.J.

A. M. Johnson . . . has been elected president of Debevoise-Anderson Co., New York. His former position—vice-president of the firm's Philadelphia office—has been filled by C. E. Gillespie.

Arthur Van Newkirk . . . is the new foundry superintendent of Abrasive Alley Castings Co., Bridgeboro, N.J.

Dr. J. G. Pearce . . . retired as director of The British Cast Iron Research Association, Alvechurch, England. **H. Morrogh** has been appointed director; **Dr. H. T. Angus** has been appointed deputy director. **T. E. Whiteside,** A.C.A., will continue as secretary with special duties in regard to the Association's finances.

Dr. Pearce has held the post of director since 1924 and is internationally known for his work in iron founding. He is co-author with **Sir Arthur Fleming** of two textbooks on apprentice training and research in industry.

R. M. Trent . . . has been elected president of Pangborn Corp., Hagerstown, Md. Trent has been with the firm for 28 years. **R. H. McCauley** was elected director of the corporation.

Clyde Williams . . . renowned metallurgist and former president of Battelle Memorial Institute, has been awarded the James Douglas Gold Medal, of the American Institute of Mining, Metallurgical, and Petroleum Engineers, one of the most distinguished honors in the field of metallurgy. Williams, who is the author of more than one hundred published technical papers and has received nine patents, is president of Clyde Williams & Co., industrial research and management advisers, Columbus, Ohio.

Paul von Colditz . . . general works manager of Canadian Steel Foundries Ltd., Montreal, Canada, has been elected a director of the company.

Jane A. MacTaggart . . . has been appointed sales representative for Samuel Greenfield Co., Inc., smelters and refiners of brass, bronze and aluminum. Miss MacTaggart's territory will include New York state and eastern Pennsylvania. She will headquarter in Greenfield's Buffalo office.

W. W. Clark . . . has taken a position with Anamet Laboratories, Inc., Berkeley, Calif. He is a member of AFS Northern California Chapter.

Henry W. Zimnawoda . . has been named sales manager for National Engineering Co. of Canada. He was formerly assistant sales manager for the parent company, National Engineering Co., Chicago. Zimnawoda graduated from the University of Danzig, as Mechanical Engineer and was assistant foundry superintendent of a steel and gray iron foundry in Warsaw, Poland. He has been with National since 1946.

D. S. Dalton . . . has been appointed sales representative for Thiem Products, Inc., Milwaukee. His territory will include northern and central Indiana and western Michigan. Dalton is chairman of Committee 8-R and an Executive Committee member, AFS Sand Division.

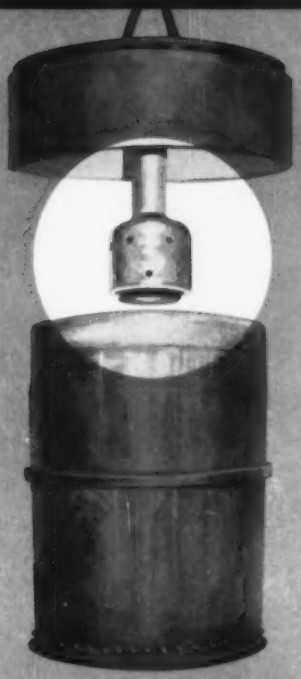
C. C. Jarchow . . . former president, was elected chairman of the board, American Steel Foundries, Chicago. He is succeeded as president and chief executive officer by **J. B. Lanterman,** vice-president since 1954. Jarchow has 47 years of service with the company—34 as an officer. **C. E. Grigsby,** vice-president since 1949, was elected a director succeeding **Thomas Drever,** retired. **G. S. Allen** was elected a director for the unexpired term of the late **G. E. Reed. R. D. Brizzolara** and **C. L. Heater** were re-elected directors.

A. F. Pfeiffer . . . has been appointed consultant for Foundry and Pattern Shops, West Allis Works, Allis-Chalmers Mfg. Co., Milwaukee. He has served as national chairman of the AFS Pattern Division and holds honorary life membership in the American Foundrymen's Society. **H. S. Evans** will fill the position as superintendent of pattern shops.

Other appointments in Allis-Chalmers are: **F. J. Bacun,** superintendent No. 2 foundry; **W. L. Olson,** superintendent No. 1 foundry; **E. H. Biersack,** assistant superintendent No. 1 foundry; **W. J. Schmidt,** superintendent brass foundry; **A. G. Knudsen,** assistant superintendent pattern shops; **H. J. Napierala;** superintendent, time study and planning; **A. J. Huebner,** general foreman, time study

Continued on page 140

DUCTILE IRON



NEW TECHNIQUE!

In plunging, a refractory basket containing the magnesium additive is plunged into an already filled ladle of iron. Flame and smoke are virtually eliminated. Slag volume is significantly reduced. Magnesium recovery is more consistent. SAVINGS OF UP TO 50% OF ALLOY COSTS ARE BEING REGULARLY OBTAINED.

SPECIAL PACKAGE

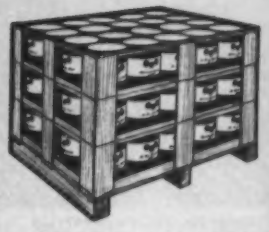
If the plunging technique fits your operation, you will be interested in Ohio Ferro-Alloys' special alloy package developed specifically for this technique. Our Sil-Mag alloys are now available in cans containing the exact weight required for specific ladle treatments. The package is designed for insertion directly in the plunger. Possible alloy losses in handling and weighing operations are eliminated.
MAXIMUM CONVENIENCE — MINIMUM COST . . .
Write for your copy of our new brochure, "Plunging Sil-Mag Alloys."

QUALITY DEPENDABILITY SERVICE

Ohio Ferro-Alloys Corporation
Canton, Ohio

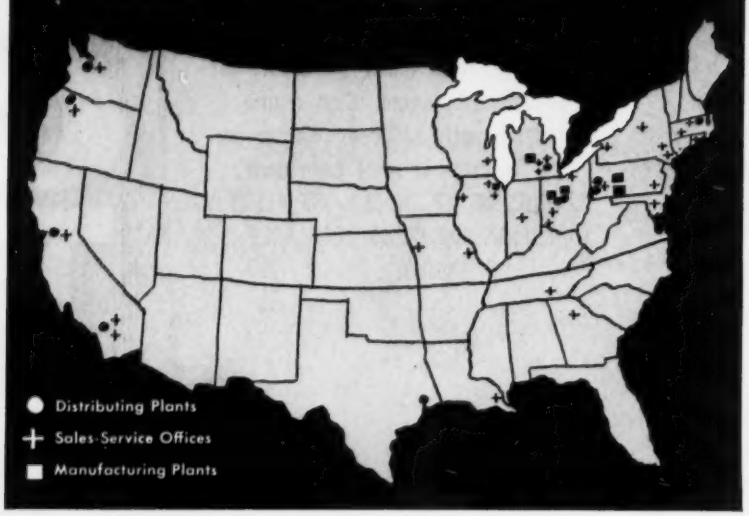
Boston • Birmingham • Chicago • Denver • Detroit • Houston • Kansas City
Los Angeles • Minneapolis • Philadelphia • Pittsburgh • Salt Lake City
San Francisco • Seattle • Vancouver, B. C.

Circle No. 719, Page 167-168



ANOTHER ADVANTAGE: Pallets holding sixty cans for convenient handling and storage.

America's leader in metal abrasives . . .



For over 70 years, Pittsburgh Crushed Steel Company has consistently led the metal abrasives industry—has led in research and product development—has led in the improvement of production methods—and has led in sales and service facilities as well as in distribution facilities!

The results have been better metal abrasives for lower cleaning costs in foundries, forge plants, and steel and metal working plants in general!

Today, through 13 distributing points and 33 sales-service offices, we supply all sizes and types of metal abrasives, iron and steel, for every type of blast-cleaning equipment and for every blast-cleaning requirement!

Our engineering, sales, and service representatives are always available to you in connection with your blast-cleaning needs.

PITTSBURGH CRUSHED STEEL COMPANY

Arsenal Sta. Pittsburgh (1), Pa.
Subsidiaries: Globe Steel Abrasive Co., Mansfield, Ohio
Steel Shot Producers, Arsenal Sta. Pittsburgh, Pa.

MALLEABRASIVE | **TRU-STEEL SHOT** | **SAMSON SHOT** | **ANGULAR GRIT**

Circle No. 720, Page 167-168

let's get personal

Continued from page 138

and planning; and **H. M. Clouse,** industrial engineer, foundry maintenance and engineering department.

obituaries

O. C. Bueg, owner of Arrow Pattern & Eng., Erie, Pa., and chairman of the AFS Pattern Division, died Feb. 7 of a heart ailment. Details of Mr. Bueg's career will appear in the April issue.

Henning Klouman, 69, technical assistant to plant manager, Bendix Lakeshore Div., Bendix Aviation Corp., St. Joseph, Mich., died Jan. 17. He was a charter member and past chairman of the AFS Michiana Chapter. Prior to joining Bendix Aviation Corp. four years ago, he had been associated with Michiana Products Corp. for 38 years.

T. Kauffmann, Sr., 92, chairman of the board of directors, S. Obermayer Co. and Ramtite Co., Chicago refractory and foundry supply firms, died January 14. He served his firm for 62 years. He was elected president in 1911 and chairman of the board in 1955.

D. P. Pigott, secretary and purchasing agent, Consolidated Brass Co., Charlotte, N. C., died recently.

J. E. Magee, 60, Chicago district sales representative, Wisconsin Centrifugal Foundry, Waukesha, Wis., and Chicago representative, Wisconsin Stainless Foundry and Machine Co., Waukesha, died recently. He had been associated with the former firm for nine years.

W. J. Johnson, 79, retired foundry superintendent, Birdsboro Steel Foundry and Machine Co., Birdsboro, Pa., died Jan. 3. He served the company in that capacity from 1946 until his retirement in 1954. From 1942 to 1946, Johnson served as plant superintendent of the government owned steel foundry operated by Birdsboro Steel Foundry and Machine Co.

C. T. Ragland, secretary and director of purchasing, Texas Steel Co., Ft. Worth, Texas, died Dec. 21.

F. Wabiszewski, vice-president, Maynard Electric Steel Castings Co., Milwaukee, died recently. He was a member, AFS Wisconsin Chapter.

I. A. Diamondstone, vice-president and treasurer, Pittsburgh Crushed Steel Co., Pittsburgh, Pa., died Jan. 7. He was a member, AFS Pittsburgh Chapter.

F. Ofner, foundry superintendent, Electric Steel Foundry Co., Portland, Ore., died recently. He was a member, AFS Oregon Chapter.

One of BERYLCO'S 3000-lb. molten metal Detroit Electric Furnaces lined with TAYCOR refractories. Photo shows test sample being taken of a beryllium-cobalt-copper alloy.

Comparative tests at BERYLCO®

show TAYCOR gives 40% longer lining life

in their Detroit Electric Furnaces

The Beryllium Corporation, Reading, Pa., world's largest integrated producer of beryllium-copper alloys, gives credit to TAYCOR (corundum-base) refractories for a 40% increase in the lining life of their Detroit Electric Furnaces.

Four 3000-lb. furnaces are operated. Three are on the job 24 hours a day (the fourth is operated 16 hours a day), six days a week, melting 10 to 12 2000-lb. heats at temperatures of 2100° to 2900° F. All of the furnaces are lined with TAYCOR. Lining life averages 900-1000 heats, ranging from 1,800,000 to 2,000,000 lbs. . . . 40% longer hard-use life than obtained from a wide variety of other refractory materials formerly used.

TAYCOR performance reports, such as this one by The Beryllium Corporation, are duplicated by many furnace operators across the nation, melting high-nickel alloys, low-carbon steel, molybdenum-tungsten steel, Ni-hard, as well as beryllium copper. Put TAYCOR to the test in your furnaces.

Exclusive Agents in Canada:
REFRACTORIES ENGINEERING AND SUPPLIES, LTD.
Hamilton and Montreal

TAYLOR ZIRCON · TAYLOR SILLIMANITE

The CHAS. TAYLOR SONS Co.
A SUBSIDIARY OF NATIONAL LEAD COMPANY

REFRACTORIES SINCE 1864 • CINCINNATI • OHIO • U.S.A.

Circle No. 721, Page 167-168

Build an idea-file for improvement and profit. The post-free cards *on the last page* will bring more information . . .

for the asking

Machining gray and nodular iron . . . 22-p booklet covers machining properties of cast iron. *Hamilton Foundry & Machine Co.*
Circle No. 561, Page 167-168

Equipment leasing . . . analyzed in booklet. *United States Leasing Corp.*
Circle No. 562, Page 167-168

New barrel finishing . . . machine incorporates vibration in operation. *Metal Finish, Inc.*
Circle No. 563, Page 167-168

Ceramic gating . . . catalog covers components for all standard cores, splash cores, elbows and tubes. For more information circle number below on Readers Service card. *Universal Clay Products Co.*
Circle No. 564, Page 167-168

Permanent molds . . . for production of metals, glass, plastics and rubber covered in 4-p bulletin. *Meehanite Metal Corp.*
Circle No. 565, Page 167-168

Pinholes or inclusions . . . is the title of newsletter which discusses inspection, causes, inclusions, improperly cleaned ladles and other factors causing these faults. *American Colloid Co.*
Circle No. 566, Page 167-168

Welders' vest-pocket guide . . . describes and illustrates in 60 pp four essentials of proper welding procedures, types of joints and welding positions. *Hobart Bros. Co.*
Circle No. 567, Page 167-168

Training courses . . . pertinent to every type of metalcasting work are offered by the AFS Training and Research Institute. For free brochure covering all courses offered, circle number below on Reader Service card. *American Foundrymen's Society.*
Circle No. 568, Page 167-168

Carbon sand . . . a new molding material composed of particles of hard carbon is described and compared with other molding sands. *J. S. McCormick Co.*
Circle No. 569, Page 167-168

Index . . . to 1957 and 1958 MODERN CASTINGS with cross references by subject title and author available. *American Foundrymen's Society.*
Circle No. 570, Page 167-168

Steel casting brochure . . . lists three basic requirements for successful product design. *Steel Founders' Society of America.*
Circle No. 571, Page 167-168

Machining manual . . . 22 pp, contains guide for machine feeds and speed, and quantity-weight slide-rule calculator. *Kaiser Aluminum & Chemical Sales, Inc.*
Circle No. 572, Page 167-168

Technical data . . . catalog free. Revised listing of pocket-size books covering every field of engineering. *Lefax Publishers.*
Circle No. 573, Page 167-168

Vacuum melting techniques . . . and high-temperature vacuum-melted alloys
Continued on page 144

M. HOLTZMAN METAL CO.

SMELTERS AND REFINERS

SINCE 1900

HOLMCO

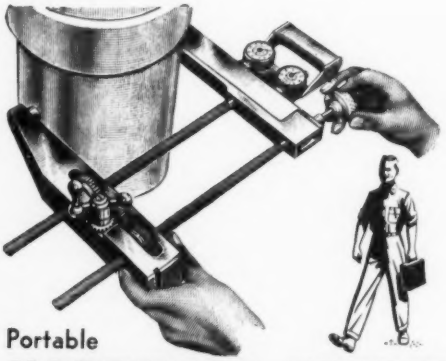
GUARANTEED Brass, Bronze and ALUMINUM INGOT to your specifications IMPROVED WITH FACTOR "X"!

Send us a sample order! If you want to improve the quality of your finished products at no additional cost . . . let us show you what HOLMCO ingot, improved with Factor "X" can mean to you!

5223 McKISSOCK AVE., ST. LOUIS, MO.

CHestnut 1-3820

Circle No. 722, Page 167-168



Portable

HARDNESS TESTER

gives "on the spot" Rockwell readings

Test materials, tools, or pieces in production "right there, right now!" Save the work of taking samples to the test bench, save the cost of sectioning, eliminate errors due to need for conversion of other scales to Rockwell hardness numbers. Large dial markings are in standard red and black for quick identification of Rockwell scales, A, B, C, D, E, F, G, H and K — all available as standard. Uses standard indentors, loads — no scale conversions required.

FOR A DEMONSTRATION, WRITE Dept. MC-359

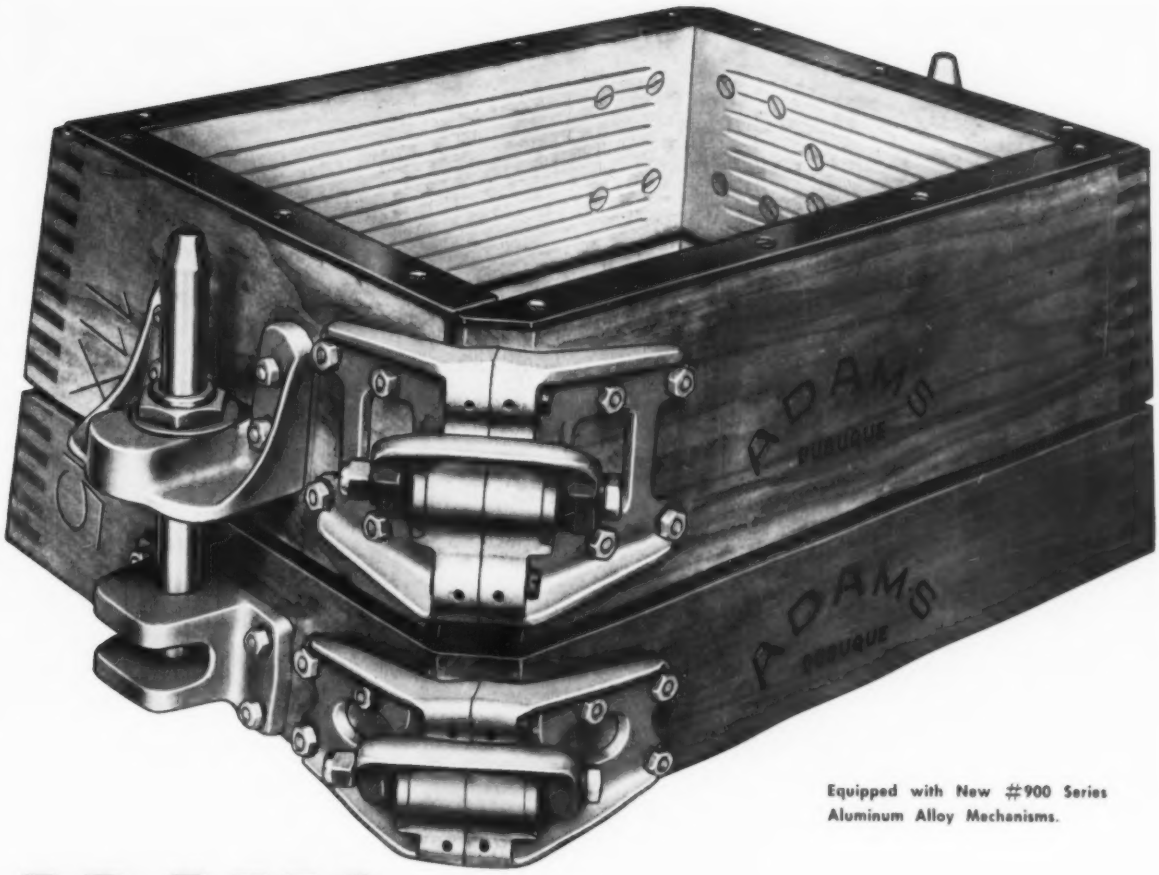
Riehle TESTING MACHINES

A DIVISION OF

American Machine and Metals, Inc.

EAST MOLINE, ILL.

Circle No. 723, Page 167-168



Equipped with New #900 Series Aluminum Alloy Mechanisms.

ADAMS CHERRY EASY-OFF FLASK

MAKE REAL SAVINGS FROM THESE ADVANTAGES!

CHERRY EASY-OFF FLASKS are of proven design and construction.

CHERRY LUMBER is the finest available, carefully selected and thoroughly air dried.

SIDES AND ENDS finished 1⅛" on all standard size flasks. 1¼" and heavier on flasks of larger perimeters and greater depths.

SOLID CORNERS are machine dovetailed and maintained in rigidness through dipping in "Hot Glue" and machine locking.

ALUMINUM ALLOY TRIMMINGS are also used on Adams Aluminum Easy-Off Flasks when specified.

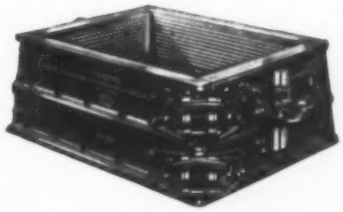
OPERATING MECHANISMS are identical with those used on the Adams Aluminum Easy-Off Flask and incorporate the same simple adjustment and reversal of locking position.

STEEL PROTECTING STRIPS are standard equipment at top, bottom and parting. Aluminum strips available upon request at no extra charge.

HANDLES AND TRUNNIONS are available when specified, Tee Iron Trusses if required.

PIN AND EAR ARRANGEMENT available to interchange with present pattern plate guides.

A COMPLETE LINE. Adams flask equipment meets your requirements in practically all methods of production. Before you invest, get the Adams story. Write today for our big profit-making catalog.



Adams Aluminum Easy-Off Flask

Adams Jackets, Cast Iron or Aluminum

The ADAMS Company

ESTABLISHED 1883

700 FOSTER ST., DUBUQUE, IOWA, U.S.A.

MOLDING MACHINES and FLASK EQUIPMENT

Circle No. 724, Page 167-168

CHILL
KOOLHEAD
NAILS
Chill Nails and Spiders
You can rely on "KOOLHEAD" and "STANHO" products
for...
ACCURATELY CONTROLLED FOUNDRY CHILLING
Write for samples and prices
Choose any style from Jumbo to Stubby; slim, medium or horse nail blade; blunt, pointed, straight or 90° bent. There's a type and size Koolhead Chill Nail or Spider Chill to do your specific chill job best.
STEEL
Stanho
PRODUCTS
the Quality Line
•WOODRUFF KEYS
•MACHINE KEYS
•MACHINE RACK
•TAPER PINS
•COTTER PINS
•SPECIAL PARTS
and other Stanho products Bulk or Packaged
WRITE for CATALOG and PRICES
STANDARD
Since 1872
HORSE NAIL CORP.
NEW BRIGHTON, PA
Circle No. 726, Page 167-168

Circle No. 747, Page 167-168

for the asking

Continued from page 142

covered in brochure. *General Electric Co., Metallurgical Products Dept.*
Circle No. 574, Page 167-168

Materials handling . . . flow plan technique for conveyor application presented in 56-p bulletin. *Rapids-Standard Co.*
Circle No. 575, Page 167-168

Manufactured graphite . . . technical data offered in handbook. *National Carbon Co., Div. Union Carbide Corp.*
Circle No. 576, Page 167-168

Shell casting . . . featured in monthly publication. *Cooper Alloy Corp.*
Circle No. 577, Page 167-168

Foundry practice . . . bulletin includes four technical articles dealing with: aluminum rotor castings, copper-tin alloys, pressure and exothermic feeding of iron castings and heat treatment. *Foundry Services, Inc.*
Circle No. 578, Page 167-168

Metalcasting technology . . . experts have written many books and manuals which are available through AFS. A complete, classified list is yours when you use the circle number below. *American Foundrymen's Society.*
Circle No. 579, Page 167-168

so tired
of old-time methods?
learn all about
latest methods from
manufacturer's
spec sheets and
catalogs
circle numbers
on card, last page
this issue

High-purity tantalum . . . is available in powder, vacuum melting stock and arc-cast ingot. Learn about this material in new, 4-p folder. *National Research Corp.*
Circle No. 580, Page 167-168

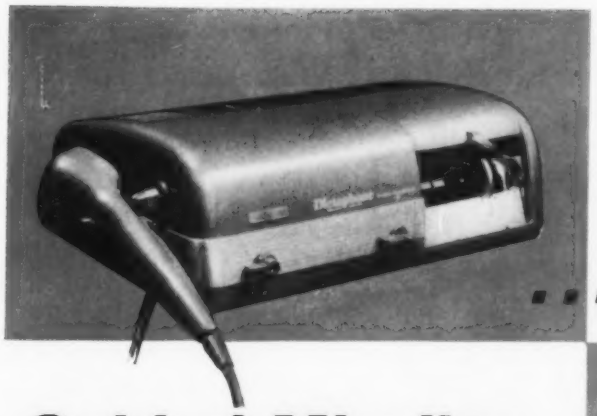
Gases in cast iron . . . are discussed with special reference to pickup of hydrogen in sand molds. This is a complete technical article from MODERN CASTINGS. *American Foundrymen's Society.*
Circle No. 581, Page 167-168

Molybdenum . . . its role in steel castings, thoroughly discussed in 36-p booklet prepared at Case Institute of Technology for Steel Founders Society. *Climax Molybdenum Co.*
Circle No. 582, Page 167-168

Initial writeoff . . . provision of Internal Revenue Code and how it effects depreciation plans for your foundry explained in brochure. *Machinery and Allied Products Institute.*
Circle No. 583, Page 167-168

Five wear resistant alloys . . . for investment castings. Complete guide to

Continued on page 146



. . . Dictaphones

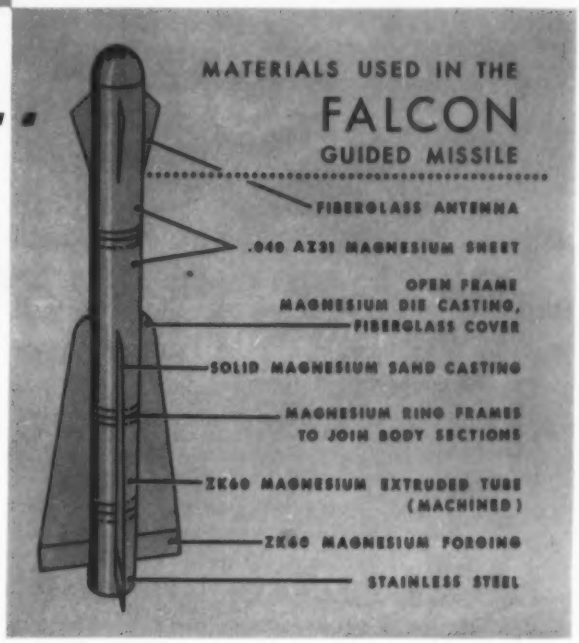
Guided Missiles . . .

OR

1001 other places

Wherever Reliability
and a high Strength-to-Weight Ratio
are of PRIMARY IMPORTANCE

People depend on MAGNESIUM



A modern metal solving modern problems
for modern designers and process engineers.

Have you checked the added qualities offered
by the new Magnesium Alloys? Write for information.

THE MAGNESIUM ASSOCIATION

122 East Forty-second Street, New York 17, New York

Circle No. 725, Page 167-168

Pallet loads of castings move to the shipping department on the forks of this 4,000-lb truck. Similar loads can be transported efficiently from shake-out to snagging and grinding rooms or any other area.

Operators like them best ... drive them best

ALLIS-CHALMERS FORK TRUCKS

"Feels like a car with power steering," says Arthur B. Wiley, fork truck driver at a Michigan factory. Further, an Allis-Chalmers truck "works fine in narrow aisles. It has no controls on the floor—easy to get on and off of."

"Must have been engineered for the driver," says operator Gast at a Wisconsin foundry. "Shifting is handy and I like where the controls are located. Have plenty of room for driving."

"I just like the whole machine — everything about it," sums up John Cromer, operator at a Missouri plant. "It's a work horse. It handles and operates smoother and performs better than others we have had in the plant."

Outstanding performance starts with the Allis-Chalmers industrial heavy-duty engine. It provides extremely high torque in relation to rated capacity for smoother operation, climbing grades, moving heavy loads.

Be "Years Ahead" with Allis-Chalmers Material Handling Equipment tells more about why operators "like them best . . . drive them best." Send for your free copy — and see your dealer. Allis-Chalmers, Milwaukee 1, Wis.

ALLIS-CHALMERS

BH-103

Circle No. 727, Page 167-168

for the asking

Continued from page 144

properties and processing. Circle number below on Reader Service card for more information. *Haynes Stellite Co.*

Circle No. 584, Page 167-168

Welding positioners . . . and importance of ground current conduction discussed in 13-p booklet. *Aronson Machine Co.*

Circle No. 585, Page 167-168

Pneumatic temperature controllers . . . and recorders described in 4-p folder. *Partlow Corp.*

Circle No. 586, Page 167-168

Tape recordings . . . of technical talks on many facets of the metal castings industry are available from AFS. Includes discussions on cupola operation, air pollution control, self-curing oil binders, producing quality castings and many more. *American Foundrymen's Society.*

Circle No. 587, Page 167-168

Core blowing . . . and mold blowing machines described in 32-p booklet listing features and applications. *Beardsley & Piper, Div. Pettibone Mulliken Corp.*

Circle No. 588, Page 167-168

Sand binder . . . formulated material which gives foundrymen a means of bonding sand without use of water, explained in brochure. Uses oil and catalyst. *Baroid Div., National Lead Co.*

Circle No. 589, Page 167-168

Selling facts . . . of product publicity discussed in monthly publication available when you circle number below. *Jordan & Van Deusen Co.*

Circle No. 590, Page 167-168

Conversion factor . . . wall-chart reference table for engineers and executives to speed up location of factors used daily. *Precision Equipment Co.*

Circle No. 591, Page 167-168

Vacuum die casting . . . both the hot-chamber and cold-chamber processes are covered in this technical article from MODERN CASTINGS. *American Foundrymen's Society.*

Circle No. 592, Page 167-168

Temperature conversion . . . chart, wallet-size, with easy-to-read tables of Fahrenheit and Centigrade temperature equivalents. *Moeller Instrument Co.*

Circle No. 593, Page 167-168

Microscopic photography . . . data book of the elementary photomicrographic technique available in a revised edition. *Eastman Kodak Co.*

Circle No. 594, Page 167-168

Inoculants . . . for cast and ductile iron described in booklets which use pictures, graphs and tables to show advantages. *Electro Metallurgical Co., Div. Union Carbide Corp.*

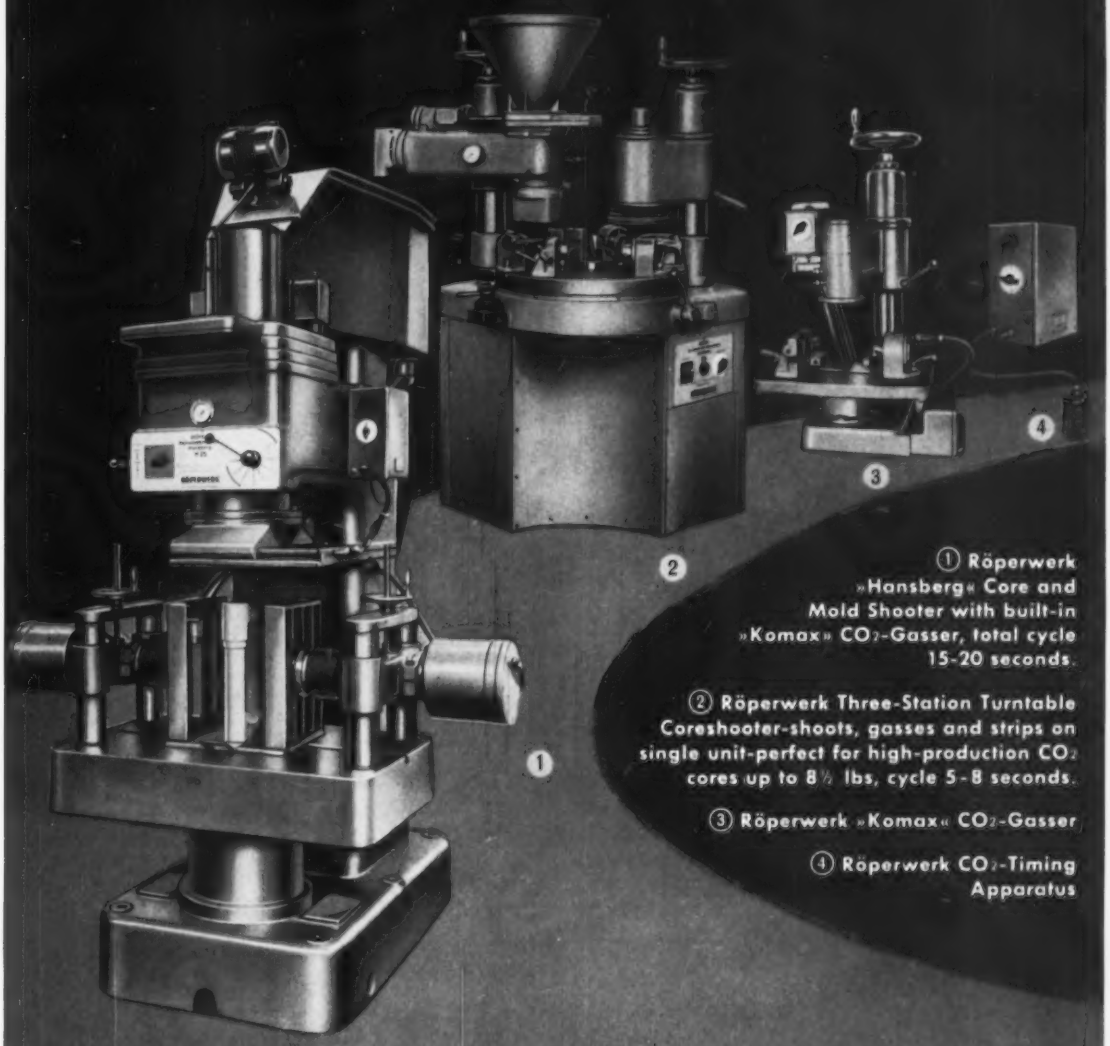
Circle No. 595, Page 167-168

Birth of gray iron castings . . . related in

Continued on page 148

CO_2

Hansberg Shooters and »Komax« Gassers for CO_2-Cores and Molds



① Röperwerk »Hansberg« Core and Mold Shooter with built-in »Komax« CO_2-Gasser, total cycle 15-20 seconds.

② Röperwerk Three-Station Turntable Coreshooter-shoots, gasses and strips on single unit-perfect for high-production CO_2 cores up to 8½ lbs, cycle 5-8 seconds.

③ Röperwerk »Komax« CO_2-Gasser

④ Röperwerk CO_2-Timing Apparatus

HANSBERG SHOOTERS, INCORPORATED

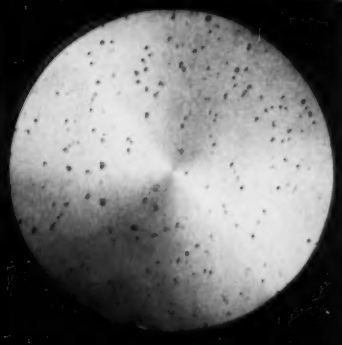
P. O. BOX 729 · EVANSTON · ILLINOIS · USA

Hansberg Shooters, Röperwerk Komax CO_2-Gassers and other Foundry Equipment

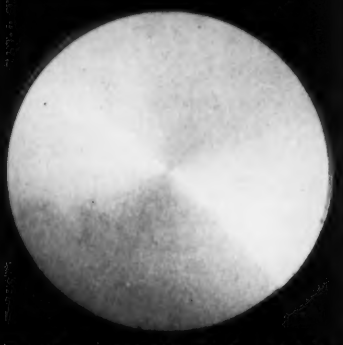
Circle No. 728, Page 167-168

Foseco COVERALS AND NEW, HIGHLY EFFICIENT DEGASERS

ELIMINATE PINHOLE POROSITY AND OXIDES IN ALUMINUM CASTINGS, BILLETS AND SLABS . . .



Pinhole porosity which resulted with untreated aluminum alloy casting.



Pinhole porosity is eliminated completely when casting is treated with Foseco COVERALS and DEGASERS.

save time and materials

- Speedily remove hydrogen from all aluminum alloys
- Minimize oxidation
- Help remove dirt and non-metallics from the melt
- Produce drosses low in metal content
- Prevent oxide build-up in furnaces
- Help prevent blistering

Efficient Foseco Coverals and *new* Foseco Degasers are available for use in all types of melting furnaces, and for treating *all* aluminum alloys.

Foundry Services, Inc. maintains a continuing research and development program to create more efficient products to insure you high quality metals at a low cost. Consult us for assistance on any of your metal treatment problems. There's no obligation.

FOUNDRY SERVICES, INC.

2000 BRUCK STREET COLUMBUS 7, OHIO

In Canada: FOUNDRY SERVICES (CANADA) LTD., 201-7 Alice St., Guelph, Ontario

Send this coupon for free leaflets giving all the facts about treating aluminum alloys.

Name_____

Company_____

Address_____

City_____ State_____

Circle No. 729, Page 167-168

for the asking

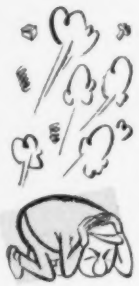
Continued from page 146

technical, colorful, 20-p book. *Pittsburgh Coke & Chemical Co.*

Circle No. 596, Page 167-168

Radiography . . . in modern industry handbook, 140 pp, well illustrated, for engineer or student. *X-Ray Div., Eastman Kodak Co.*

Circle No. 597, Page 167-168



don't give up! whatever your problem, you'll get the advice of experts if you use the reader service card on last page

The following reprints of feature articles which appeared in MODERN CASTINGS are available to you free of charge. Use the Reader Service card, last page.

Circle No. 598, Page 167-168

Induction melting . . . reprint from MODERN CASTINGS features centrifugal casting of 60,000-lb stainless steel paper mill roll. *American Foundrymen's Society.*

Circle No. 599, Page 167-168

Calcium carbide injection . . . process is subject of article reprinted from MODERN CASTINGS. *American Foundrymen's Society.*

Circle No. 600, Page 167-168

Coremaking . . . for use in fabrication of steel castings involves use of corn-sugar binder. Circle number below on Reader Service card, last page, for your free reprint of this MODERN CASTINGS article. *American Foundrymen's Society.*

Circle No. 601, Page 167-168

Low-cost winter heating . . . using infra-red heaters is explained in free reprint of article which appeared in MODERN CASTINGS. *American Foundrymen's Society.*

Circle No. 602, Page 167-168

Carbon refractories . . . in cupola construction is subject of article reprinted from MODERN CASTINGS. *American Foundrymen's Society.*

Circle No. 603, Page 167-168

Olivine aggregate . . . as a molding material. A study by the University of Washington, Seattle, is available as a reprint. Use the Reader Service card, last page, for your copy. *American Foundrymen's Society.*

Circle No. 604, Page 167-168

Titanium castings . . . a complete report on the markability and cost is included in this reprint from MODERN CASTINGS. *American Foundrymen's Society.*

Circle No. 605, Page 167-168

PERMABRASIVE®

how precise can *You* be in your blast cleaning room?

Blast cleaning is admittedly a job of many variables, hard to keep on an even keel. Involved in economical blast cleaning are such things as good housekeeping, good control over equipment and, of course, good shot and grit. Many blast cleaning troubles develop, because the characteristics of many abrasives vary with each shipment!

NATIONAL has developed its ability to give you abrasives with controlled characteristics ton after ton after ton. This eliminates the *one* variable over which you have no control and makes possible staggering savings. Cost-conscious customers have enjoyed this NATIONAL advantage for over a decade!

Exactly what is YOUR application? Are you using steel? **PERMABRASIVE**® can save money through faster cleaning and lower costs per ton. Are you using an ordinary annealed abrasive? **PERMABRASIVE**® can save money through faster cleaning, minimum graphitic carbon content, and longer life, because of a low phosphorus content. Are you using chilled? **CONTROLLED "T"**® can save money up to 50% on consumption and up to 40% on maintenance costs, because of its controlled BHN: an iron fist (for the product to be cleaned) in a velvet glove (to be kind to blast cleaning machinery). Have you a tough, individual problem? NATIONAL'S metallurgists KNOW what it takes to reach an objective and KNOW how to produce a custom-made abrasive for a specific job!

We're not just talking to hear our own voices. Everything can be proven to you in your own plant under your own conditions as it has in thousands of other cases—without an operation-disturbing test. Try us!

FREE: the NEW "Second Reader on the use of shot and grit." Write for your copy.

Sold Exclusively by
HICKMAN, WILLIAMS & COMPANY (Inc.)
Chicago · Detroit · Cincinnati · St. Louis · New York · Cleveland · Philadelphia · Pittsburgh · Indianapolis

Exclusive West Coast Subdistributors
BRUMLEY-DONALDSON COMPANY
Los Angeles · Oakland

NATIONAL
METAL ABRASIVE COMPANY
3560 Norton Rd. · Cleveland 11, Ohio
Western Metal Abrasives Co. (Affiliate)
101 E. Main Street · Chicago Heights, Illinois
Sole manufacturers of
Permabrasive® and Controlled "T"® abrasives.

Circle No. 730, Page 167-168

At Magcobar's Des Plaines, Illinois, laboratory, A. H. Zrimsek uses modern methods for foundry sand research.

SCIENCE and SAND

. . . Recipe For Progress

In new laboratories at Des Plaines, Houston and Greybull Magcobar technicians are busy with silica, bentonite, water and a host of other ingredients, taking the guesswork out of sand formulas. Applying modern research methods, these scientists are *proving* the "hows" and "whys" of foundry sand practice.

Magcobar invites the technical and research groups of the American Foundries to use Magcobar facilities for the solution of various industry-wide problems relating to sands.

Write Des Plaines for our latest foundry technical bulletins. Look to Magcobar, producers of YELLOWSTONE bentonite, for further revealing recipes for progress.

Magcobar
YELLOWSTONE
BENTONITE

MAGNET COVE BARIUM CORPORATION

Des Plaines, Illinois, 576 Northwest Highway
Houston, Texas, P. O. Box 6504
Greybull, Wyoming

Magcobar technicians in the company's big research laboratories in Houston strive for constant improvement of Magcobar products.

This Magcobar plant at Greybull, Wyoming, where YELLOWSTONE is mined and processed, is the world's largest producer of bentonite, and includes a complete quality-control laboratory.

Want to know more about STAINLESS Castings?

Designing for corrosion or high temperature service?

You can get all the engineering facts on 28 heat and corrosion resistant casting alloys in this indexed folder of ACI Data Sheets. Take advantage of the availability of the full range of CAST alloys!

In these data sheets, buyers too will get practical help–especially from the lists of specifications and equivalent designations.

DESIGN FACTORS

- **Mechanical Properties**
- **Specifications**
- **Heat Treatments**
- **Physical Constants**
- **Temperatures**
- **Welding**
- **Machining**
- **Corrosives**
- **Applications**
- **Alloys**

Send for your set of Data Sheets–free, of course.

Headquarters for Information on
CORROSION RESISTANT AND
HEAT RESISTANT CASTINGS

ALLOY CASTING INSTITUTE
286 Old Country Road / Mineola, New York

ALLOY CASTING INSTITUTE
286 Old Country Road, Mineola, N. Y.

Please send me a set of ACI Data Sheets ☐
I'd like a list of your publications ☐

Name _____

Title _____

Company _____

Address _____

City _____ Zone ____ State _____

Circle 750, Page 167-168

Circle No. 732, Page 167-168

At Magcobar's Des Plaines, Illinois, laboratory, A. H. Zrimsek uses modern methods for foundry sand research.

SCIENCE and SAND

. . . Recipe For Progress

In new laboratories at Des Plaines, Houston and Greybull Magcobar technicians are busy with silica, bentonite, water and a host of other ingredients, taking the guesswork out of sand formulas. Applying modern research methods, these scientists are *proving* the "hows" and "whys" of foundry sand practice.

Magcobar invites the technical and research groups of the American Foundries to use Magcobar facilities for the solution of various industry-wide problems relating to sands.

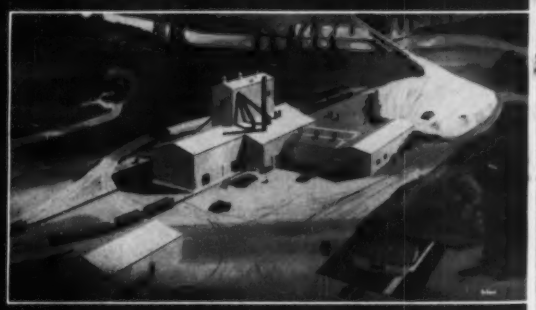
Write Des Plaines for our latest foundry technical bulletins. Look to Magcobar, producers of YELLOWSTONE bentonite, for further revealing recipes for progress.

Magcobar
YELLOWSTONE
BENTONITE

MAGNET COVE BARIUM CORPORATION

Des Plaines, Illinois, 576 Northwest Highway
Houston, Texas, P. O. Box 6504
Greybull, Wyoming

Magcobar technicians in the company's big research laboratories in Houston strive for constant improvement of Magcobar products.



This Magcobar plant at Greybull, Wyoming, where YELLOWSTONE is mined and processed, is the world's largest producer of bentonite, and includes a complete quality-control laboratory.

Want to know more about STAINLESS Castings?

Designing for corrosion or high temperature service?

You can get all the engineering facts on 28 heat and corrosion resistant casting alloys in this indexed folder of ACI Data Sheets. Take advantage of the availability of the full range of CAST alloys!

In these data sheets, buyers too will get practical help–especially from the lists of specifications and equivalent designations.

DESIGN FACTORS

- **Mechanical Properties**
- **Specifications**
- **Heat Treatments**
- **Physical Constants**
- **Temperatures**
- **Welding**
- **Machining**
- **Corrosives**
- **Applications**
- **Alloys**

Send for your set of Data Sheets–free, of course.

Headquarters for Information on
CORROSION RESISTANT AND
HEAT RESISTANT CASTINGS

ACI

ALLOY CASTING INSTITUTE

286 Old Country Road / Mineola, New York

ALLOY CASTING INSTITUTE
286 Old Country Road, Mineola, N. Y.

Please send me a set of ACI Data Sheets ☐
I'd like a list of your publications ☐

Name _____

Title _____

Company _____

Address _____

City _____ Zone ____ State _____

Circle 750, Page 167-168

Circle No. 732, Page 167-168

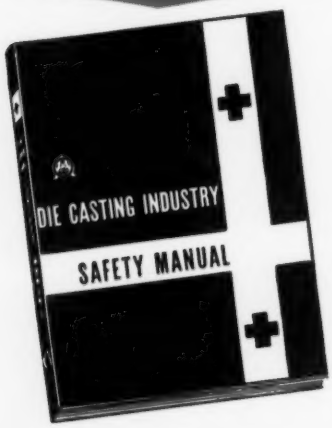
3 SYMBOLS TO GUIDE DESIGN ENGINEERS

FOR ECONOMY IN DIE CASTING

The **ADCI PRODUCT STANDARDS FOR DIE CASTINGS MANUAL** is designed to help product engineers to get the most from the die casting process.

The **ADCI DIE CASTING INDUSTRY SAFETY MANUAL** is designed to improve operating safety in die casting plants. These **MANUALS** are available from the address below at $5.00 each.

FOR SAFETY IN DIE CASTING



REPUTATION

MEMBER COMPANY OF THE AMERICAN DIE CASTING INSTITUTE

The national association of the custom die casting industry. The qualified ADCI members produce over 75% of the nation's annual volume of aluminum, magnesium, zinc and copper alloy die castings produced for sale.

QUALITY

A PARTICIPANT IN THE CERTIFIED ZINC ALLOY PLAN

The CZ Plan was developed by the American Die Casting Institute to permit you to select, with confidence, your supplier of zinc die castings. The CZ symbol is your assurance that the castings you buy will meet ADCI and ASTM standard specifications.

GROWTH

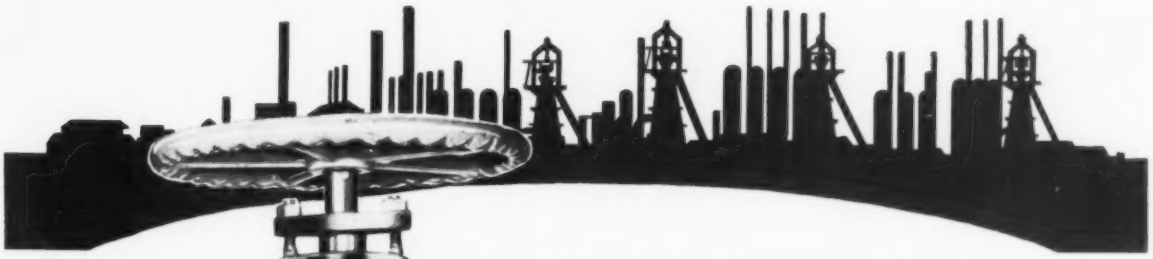
DIE CASTING RESEARCH FOUNDATION PARTICIPANT

A PARTICIPANT IN THE DIE CASTING RESEARCH FOUNDATION

These die casting suppliers have behind them the vast knowledge of improved die casting procedures being accumulated through the Die Casting Research Foundation.

AMERICAN DIE CASTING INSTITUTE 366 MADISON AVENUE, NEW YORK 17, N. Y.

Circle No. 733, Page 167-168



14" Diameter Valve
Manufactured by
STOCKHAM VALVES
& FITTINGS
Birmingham, Ala.

WOODWARD IRON

Gives Rugged Strength to Quality

STOCKHAM VALVES

This 2000 lb., 54" high, water and gas Double Disc Gate Valve, with bolted by-pass, was manufactured by STOCKHAM VALVES & FITTINGS, in its modern plant at Birmingham, Ala. It is typical of many sturdy, precision castings that are being made today of Woodward iron by the nation's leading foundries.

Quality Stockham valves are produced in a size range from 2" through 30". They efficiently co-ordinate rugged, balanced strength to withstand wear and insure dependable performance with the latest features of approved design.

Woodward invites inquiries from foundries requiring iron of uniform analysis for production of castings that must meet the strictest standards of exacting buyers.

For quotations, write or call our Sales Department, Woodward, Ala.
Phone Bessemer, Ala. HAmilton 5-2491
or Sales Agents for territory North of Ohio River:
HICKMAN, WILLIAMS & COMPANY with Sales Branches at—

609 Bona Allen Building, Atlanta 3, Ga.; 230 North Michigan Avenue, Chicago 1, Ill.; First National Building, P. O. Box 538, Cincinnati 1, Ohio; 1659 Union Commerce Building, Cleveland 14, Ohio; 1203 Ford Bldg., Detroit 26, Mich.; P. O. Box 335, Duluth 1, Minn.; 412 Guaranty Bldg., Indianapolis 4, Ind.; 70 Pine St., New York 5, N. Y.; 1500 Walnut Street Bldg., Philadelphia 2, Pa.; 1910 Clark Bldg., Pittsburgh 22, Pa.; 902 Syndicate Trust Bldg., St. Louis 1, Mo.

WOODWARD IRON COMPANY

WOODWARD IRON COMPANY

WOODWARD, ALABAMA

Independent Since 1882

Circle No. 734, Page 167-168

One core oil does it!

Every piece made with Cities Service Delco 58 Core Oil!

Brass Foundry Company in Peoria, Illinois, pours 1,600,000 pounds of brass and aluminum castings per year . . . keeps six core makers constantly busy . . . yet requires only *one* core oil—Cities Service Delco 58.

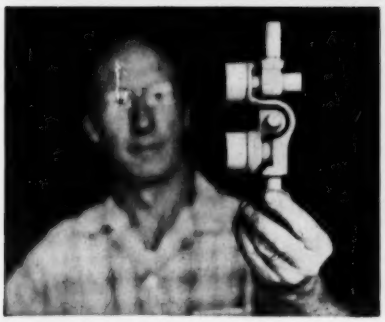
Unusual under any circumstances, this achievement is all the more significant when you realize that the cores are made for castings that must be extremely precise . . . castings made to the demanding specifications of the automotive, aviation, electrical, and agricultural industries.

Cities Service Delco 58 meets every core oil requirement because, in the words of foreman Arthur King, **"the oil is uniform from batch to batch, gives good workability, and fast-bake, has low gas content and excellent shakeout properties."**

Little can be added to Mr. King's statement except this suggestion: If you're not getting comparable results with *your* core oil, it's time to talk with a Cities Service Core Oil Specialist. Call the nearest office or write: Cities Service Oil Company, 20 North Wacker Drive, Chicago 6, Illinois.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS



Top This For Complexity! Few cores can surpass the complex design of this one, held by core room foreman Arthur King. Like all others, it is made with Cities Service Delco 58 Core Oil.

Grandma Never Baked Like This! . . . but Grandma couldn't have taken greater pains than they do at Brass Foundry Company. One great asset is the fast-bake qualities of Cities Service Delco Core Oil.

1,600,000 Pounds Of Brass And Aluminum Castings are poured each year at Brass Foundry Co. They are made to the demanding specifications of the electrical, agricultural, aviation, and auto industries.

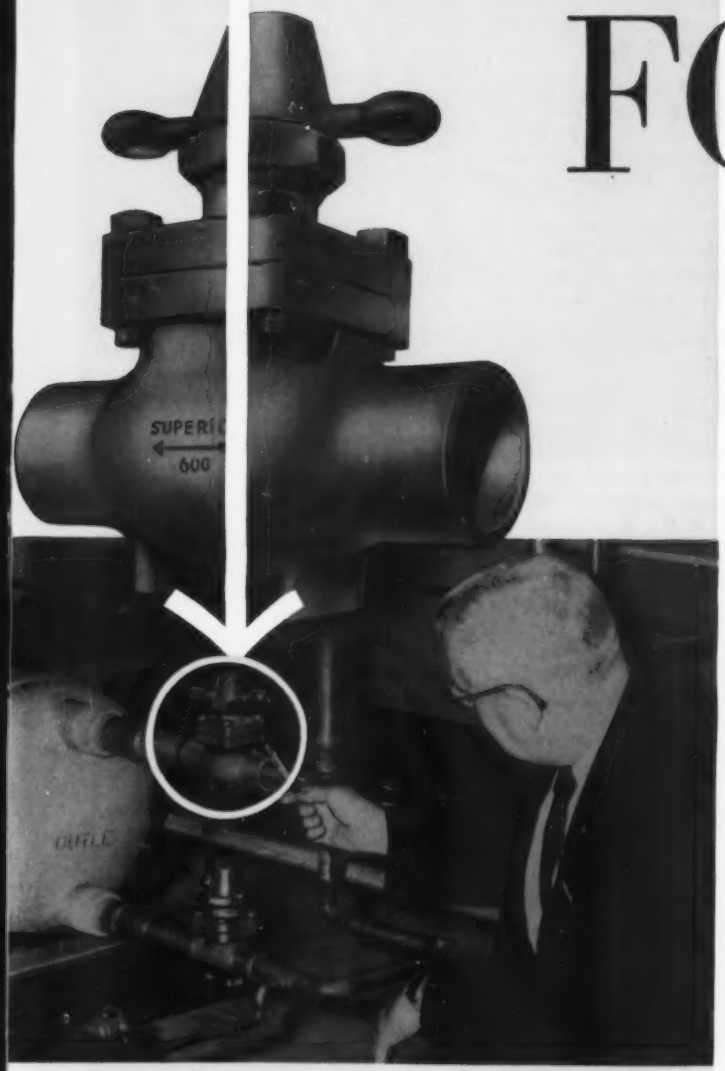
Circle No. 735, Page 167-168

NO. **1** Case History of a Challenge

How industry relies on non-ferrous castings

WANTED! *A Valve with non-corrosive and pressure-tight properties for use on a large Air Conditioning Unit*

FOUND!



Bronze Valve manufactured by SUPERIOR VALVE & FITTINGS CO., Pittsburgh, Pa.

A Valve machined from a Bronze Casting that more than met the exacting specifications.

Here is a manufacturer of Air Conditioning Equipment who learned that you can "*install it and forget it*" when the Casting is non-ferrous! For non-ferrous alloys show *greater* corrosive-resistant properties than other materials and—also offer versatility of alloy control . . . simplicity of tooling . . . uniform wall sections . . . less machine time . . . more intricate patterns . . . and, usually, lower tooling costs.

Investigate non-ferrous castings . . . you may be *many dollars ahead.*

FREE! A valuable Brass-Bronze-Aluminum Chart for your wall. Shows properties and specifications of all popular alloys. Write today.

WALL CHART

Shows properties and specifications of all popular Brass, Bronze, and Aluminum Alloys. Mailed free.

NON-FERROUS FOUNDERS' SOCIETY

University Building • 1604 Chicago Ave. • Evanston, Ill.

Please send Non-Ferrous Alloy Chart to

NAME .....

ADDRESS .....

Circle No. 736, Page 167-168

NARCAL 70 B

THE ONE MODERN HIGH ALUMINA PLASTIC REFRACTORY

for ALL your requirements!

- Electric Furnace Roofs or Center Sections
- Crucible Furnaces
- Runners
- Spouts
- Ladles (all types)

JOINTLESS CONSTRUCTION

EASE OF INSTALLATION

LONG-LASTING SERVICE

Furnished in

- 100 lb. Easy-to-Handle Cartons
- Conveniently Sized 2" Slices
- Air or Hand Ram Consistency
- Polyethylene Envelopes for Safe Storage

NORTH AMERICAN REFRACTORIES CO.
General Offices, Cleveland 14, Ohio
DISTRICT SALES OFFICES:
New York 7, N. Y.
Philadelphia 2, Pa.
Boston 10, Mass.
Buffalo 3, N. Y.
Pittsburgh 22, Pa.
Detroit 2, Mich.
Chicago 5, Ill.
Cincinnati 2, Ohio
Los Angeles, Calif.
NARCO
NORTH AMERICAN REFRACTORIES, LTD.
Hamilton, Ontario

Circle No. 737, Page 167-168

foundry trade news

Continued from page 136

Ammet develops deoxidizing alloys and degasifying compounds that improve certain properties of iron, steel and non-ferrous metals. The new representatives will distribute rare-earth metal alloys, silicon carbide and other additives to the molten metal industry.

M. A. Bell Co. . . . St. Louis, has been appointed by Ohio Ferro-Alloys Corp. as exclusive sales representative for Texas, Louisiana and Arkansas.

Debevoise-Anderson Co. . . . Boston, Mass., has been appointed exclusive New England sales representative for Ohio Ferro-Alloys Corp.

Liquid Carbonic Division . . . General Dynamics Corp., New York, has acquired Industrial Air Products of the South. The acquisition includes two plants in New Orleans, La. and Peacayoula, Miss. with a total of 60 employees manufacturing oxygen and acetylene. The new organization will be under management of Liquid Carbonic's southern region with headquarters in Atlanta. Ralph Brown was appointed sales manager of the New Orleans operation.

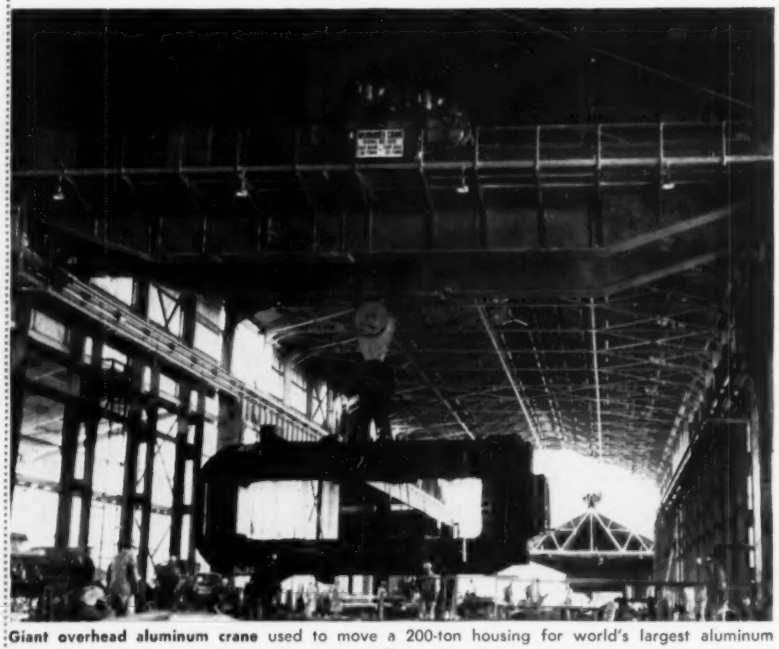
Hartzell Mfg. Inc. . . a new zinc and aluminum die-casting firm has been established in St. Paul, Minn. The company was formed by combining the assets, personnel and facilities of three established die-cast plants: Lloyd Products, Inc.; Mitee Mfg. Co.; and Production Engineering Co. The new firm is the largest die-casting operation in Minnesota.

A. P. Green Fire Brick Co. . . . Mexico, Mo., announced plans for construction of a new $2,000,000 plant for the manufacture of basic refractories, Tarentum, Pa. The new plant will produce a full line of basic refractories consisting of magnesite, magnesite-chrome, chrome-magnesite and chrome products. Production will include a complete line of basic specialty refractories including bonding mortars, plastics, castables and ramming mixes. W. G. Maloney has been appointed plant manager and will take over duties during construction. R. A. Witschey will be transferred to Tarentum as sales engineer. The Pittsburgh sales office will be under the direction of J. B. Allardice, district sales manager. He will be assisted by R. E. Fitzmier and R. W. Highley.

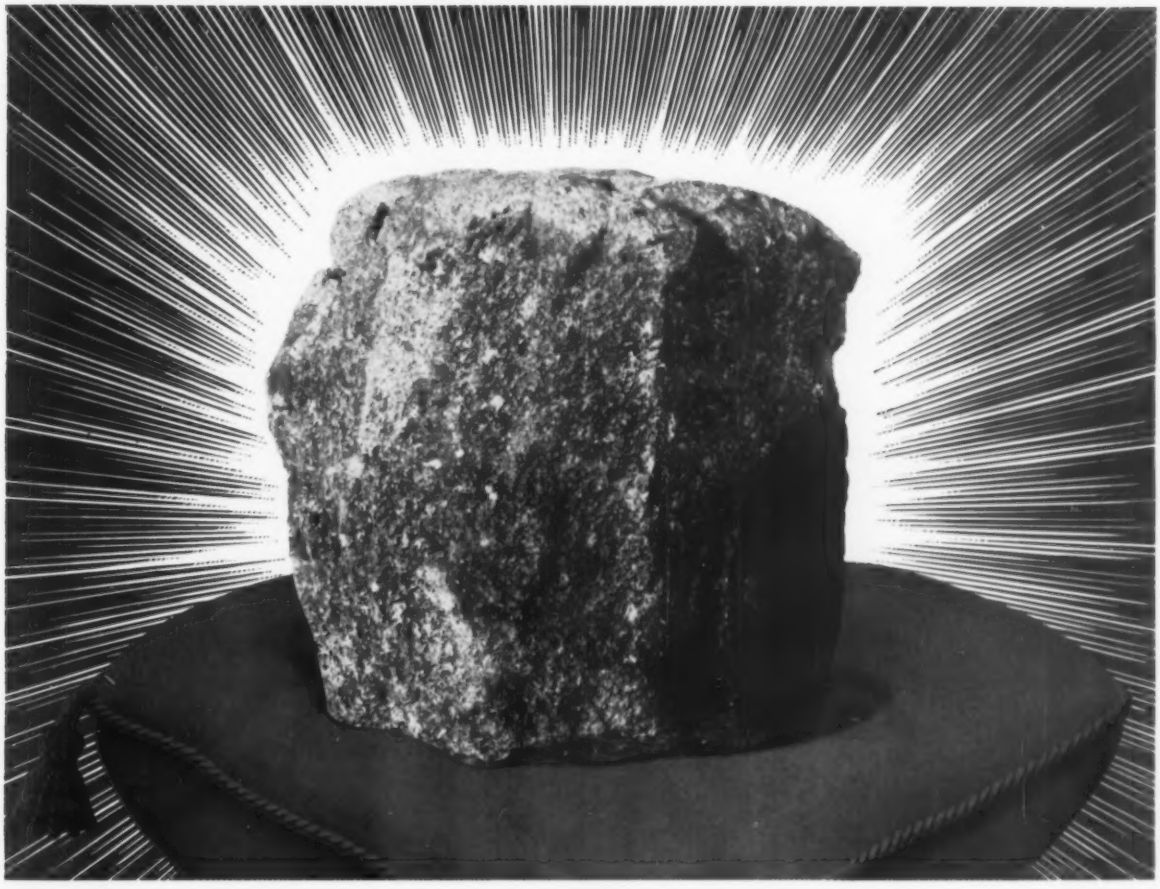
National Engineering Co. of Canada Ltd. . . . a subsidiary of National Engineering Co., took over the business of Maple Leaf Mixer, formerly manufactured by Cunningham Foundry & Machine Co., Ltd., St. Catherines, Ontario. This firm manufactured a muller-type machine.

National will continue to supply the

Continued on page 165



Giant overhead aluminum crane used to move a 200-ton housing for world's largest aluminum hot rolling mill—Reynolds Metals Co., near Sheffield, Ala. Crane said to be more than 50 tons lighter than comparable strength steel. The 150-ton rated capacity has over-all width of 32 ft and an 80 ft span.



Valuable asset: QUALITY

QUALITY—uniform quality ton after ton after ton—is one of the most important assets you can have in the coke you buy.

At Semet-Solvay, coke quality begins at the mine, where we sample every ton of coal, checking for impurities and measuring the coking qualities. At our coke plants, daily tests in sole-heated furnaces and giant test ovens detect and correct variations that might impair coke quality. Production samples are tested daily for uniformity, strength and proper chemical analysis.

Buying foundry coke from Semet-Solvay offers you other advantages, too: Four strategically located plants for fast, dependable service... five different sizes of coke to meet individual cupola and melting requirements . . . the services of metallurgical experts to assist you on foundry problems.

If you are not already using Semet-Solvay foundry coke, why not find out now how it can help you obtain a hotter, cleaner, faster cupola operation? Just contact your nearest Semet-Solvay office or write directly to us for complete details.

Sampling coal at the mine—one step in Semet-Solvay's quality-control program to assure you of better melting coke.

Allied Chemical

Yours for better melting...

SEMET-SOLVAY DIVISION

Dept. 552-BI, 40 Rector Street, New York 6, N.Y.

BUFFALO · CINCINNATI · CLEVELAND · DETROIT

IN CANADA: ALLIED CHEMICAL CANADA, LTD., SEMET-SOLVAY DEPT., TORONTO

WESTERN DISTRIBUTOR: WILSON & GEO. MEYER & CO., SAN FRANCISCO · LOS ANGELES

Circle No. 738, Page 167-168

Four Winners GIFS DESIGN Contest

Changing this compressor discharge casing to a high strength gray iron casting saved 58% in material and 34% in machining costs.

General Electric Company

Block link for chain redesigned to an iron casting eliminated 20 operations, and saved $42,000 in equipment.

The Jeffery Manufacturing Co.

This oil pump spacer when converted to cast iron eliminated carburizing and finishing operations and saved 88%.

Detroit Diesel Engine Division, GMC.

A cost reduction of up to $20 a set was made by using iron casting to make these wing-form bodymakers.

National Can Corporation

Design history is being made

BY MODERN GRAY & DUCTILE IRON CASTINGS!

Almost every day design history is being made by gray and ductile iron castings! Modern metallurgy is providing gray irons with new highs in properties . . . new molding techniques are producing castings with better surface finish and closer dimensional accuracy. Such outstanding developments are causing engineers to consider gray iron *first* in designing products. Write for the GRAY IRON CASTINGS HANDBOOK. Save money by learning more about this remarkable material.

GRAY IRON FOUNDERS' SOCIETY INC.
National City-East Sixth Building
Cleveland 14, Ohio

☐ $10 enclosed ☐ bill after 10 days
☐ Purchase Order enclosed

*Name*_____ *Title*_____
*Company*_____
*Address*_____
*City*_____ *Zone*____ *State*_____

NEW 620 page Handbook

Just off the press. Cost-cutting design and purchasing information on new ductile, regular and special iron castings. 400 illustrations, 64 tables, 263 subjects. Mail coupon for TEN DAYS FREE EXAMINATION. At the end of 10 days remit $10 or return the book.

GRAY IRON FOUNDERS' SOCIETY

Circle No. 739, Page 167-168

View of Gray Iron Pallet System. Pallets can be easily moved over rails by hand. Left: Plant Engineer Robert H. Clarke. Right: Scale mounted on fork truck weighs each component of charge.

ENGINEERING APPLICATIONS PAY OFF AT DALTON FOUNDRIES

INCREASED EFFICIENCY

To obtain faster, more efficient, production in the company's gray iron foundry, Robert H. Clarke, Plant Engineer at Dalton Foundries, Inc., Warsaw, Indiana, designed a pallet system. This flexible system allows molders to work two hours before pouring needs to begin. Cooling time can be varied to suit the job and pallets can be easily moved over rails by hand. No bottom boards are used and the handling formerly required to bring them back to the molders has been eliminated. The pallet system provides flexibility for both production and jobbing type work.

BETTER CONTROL

When bond and water are added to sand during mulling, the bond must be thoroughly combined with water to be effective. Plant Engineer Clarke designed a system to pre-mix water and bond, and pump the mixture into a storage tank where it is stirred continually. From the storage tank, small amounts of the mixture are metered into a tank by a timer. Compressed air then blows this metered amount into the muller at the correct time. This system has resulted in better control of sand, faster mulling cycles, and easier handling of materials.

LOWER COST

At the Dalton Foundries the old wheelbarrow method used to charge the cupola required seven men. Clarke designed a scale which could be mounted on the front of a fork truck to weigh each component of the charge as it was loaded into a drop-bottom tub on the truck. After it is loaded, the fork truck delivers the material to the charging bucket. This simple, and inexpensive engineering change reduced the labor requirement to three men instead of the seven previously required.

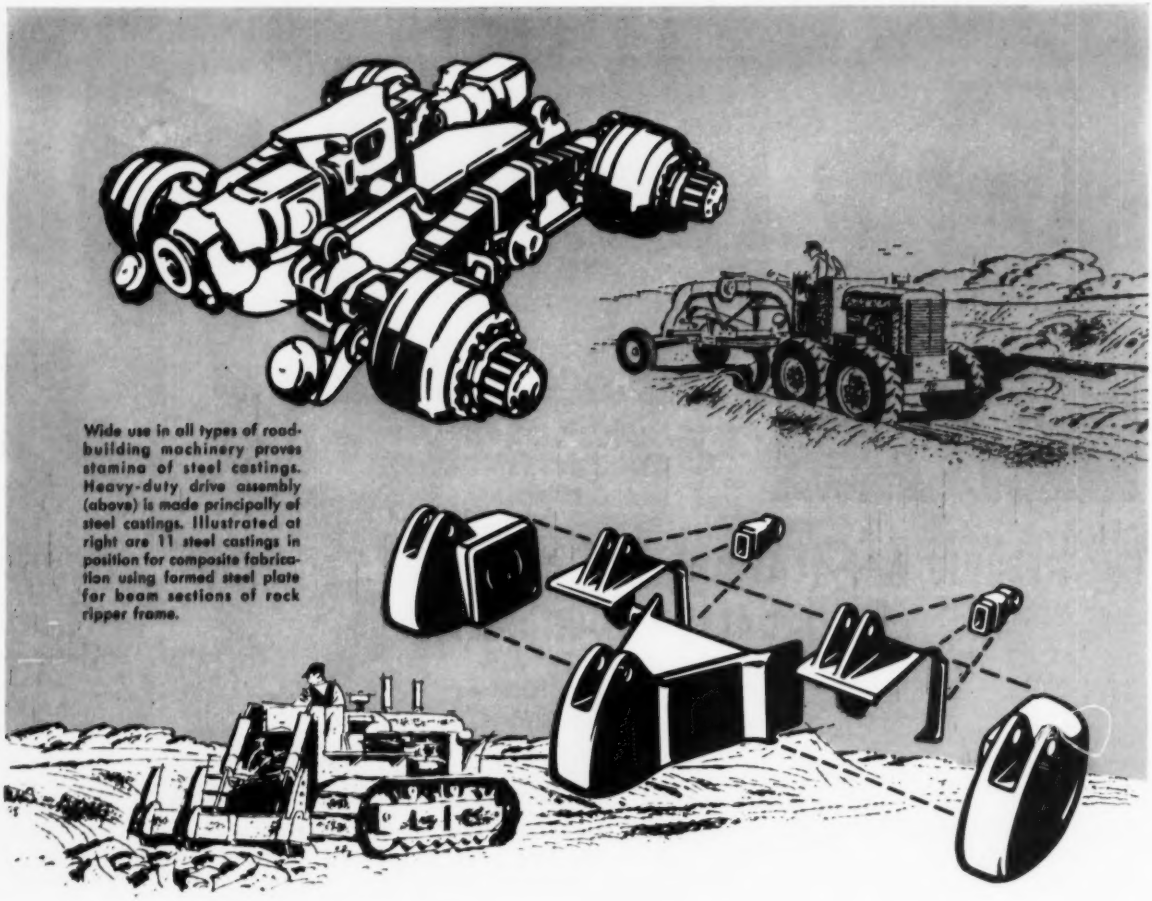
You can help create a source of engineering talent for the foundry industry by participating in the FEF program as a contributing member.

Foundry Educational Foundation

1138 TERMINAL TOWER BUILDING • CLEVELAND 13, OHIO

Space contributed by **Modern Castings** as another service to the metal castings industry.

Circle No. 740, Page 167-168



Wide use in all types of road-building machinery proves stamina of steel castings. Heavy-duty drive assembly (above) is made principally of steel castings. Illustrated at right are 11 steel castings in position for composite fabrication using formed steel plate for beam sections of rock ripper frame.

Design

RUGGEDNESS

Into Your Products... Use STEEL CASTINGS

In all types of equipment and machinery, you'll find steel castings at key points. They combine the highest degree of strength and impact resistance with optimum design and production advantages.

Uniform structure throughout... advantageous distribution of metal... dimensional stability... good machinability... ease of welding... resistance to shock... wide range of mechanical and chemical properties... good magnetic or non-magnetic characteristics. All these are basic advantages of steel castings.

Design *your* products with steel castings. Obtain the functional requirements at most favorable end cost. And be assured of long service life with low maintenance.

STEEL FOUNDERS' SOCIETY OF AMERICA
606 TERMINAL TOWER • CLEVELAND 13, OHIO

Build With Steel Castings

Send For Informative Literature:

Reference Chart of Steel Castings' Properties.
32-page booklet:
"Fatigue Properties of Cast and Comparable Wrought Steels".
Product Design Studies on steel castings for products you manufacture.

Circle No. 750, Page 167-168

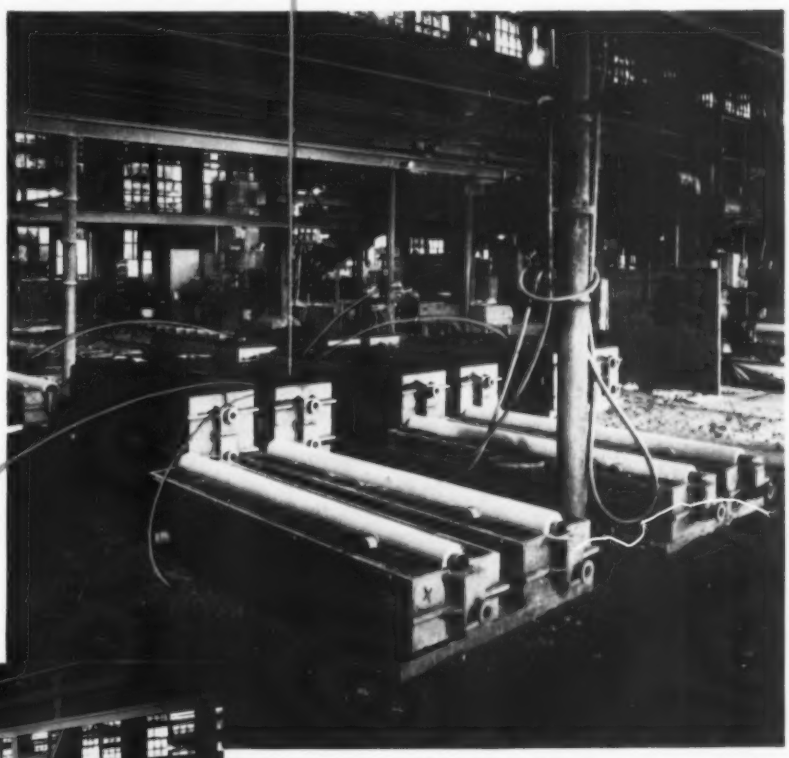
Cut Casting Costs with STERLING Flasks

Famous Rolled Steel Channel Construction Assures Greater Accuracy... Adds Many Years to Flask Life!

Leading foundrymen have learned from experience they can greatly reduce casting costs by using Sterling Rolled Steel Channel Flasks. The Kennedy Valve Mfg. Co., Elmira, New York, for example, has used Sterlings for more than 25 years. The vice-president of this progressive foundry states:

"Our foundries are strictly tight flask shops, because we have so many thousands of jobs in which perfect registration of cope and drag is necessary, due to our transfer method of molding from half patterns. We have gone through the entire gamut of flasks, from home-made cast iron and aluminum, through fabricated steel, to heavy cast steel, and have found that we get the best overall dollar value from Sterling Flasks. We especially appreciate your generous engineering service, your honest recommendation of the type, size, and weight of flask to use for the job, and for your prompt handling of orders."

So why not play safe? Buy Rolled Steel Channel Flasks. They last longer... produce better castings... cost less per year. Top quality pays off in dividends.



• Kennedy Valve Mfg. Co. foundry uses Sterling Steel Flasks almost exclusively. Standpipes for water hydrants are held to close tolerances, using Sterling Special ⅜" NS-RT Flasks.

Sterling

STERLING NATIONAL INDUSTRIES, Inc.

Founded 1904 as STERLING WHEELBARROW CO. • Milwaukee 14, Wisconsin, U.S.A.

Subsidiary Company: STERLING FOUNDRY SPECIALTIES LTD. • LONDON • BEDFORD • JARROW-on-TYNE, ENGLAND

PIONEERS IN THE MANUFACTURE OF FOUNDRY FLASKS AND EQUIPMENT

A8-4526

Circle No. 741, Page 167-168

Whatever you require
of a metal...

you get more with Malleable

High Strength — If you need strengths in the 50,000 p. s. i. to 135,000 p. s. i. tensile range, you can pick a Malleable iron to fit your exact needs. More important, corresponding yield strengths run from 32,500 p. s. i. to 110,000 p. s. i. Malleable delivers more strength per dollar than any other metal — ferrous or non-ferrous.

Toughness and Ductility — Parts that must stand up under rugged conditions demand Malleable. Malleable castings are experience proven by their successful record in rough service applications. And ductility is inherent *without* special, costly alloying.

Unexcelled Machinability — Whenever a part must be highly machined, you're certain to save time, tools and money with Malleable: The most machinable of all ferrous metals of similar properties. And, many machining operations are eliminated by changing to a casting.

Design Flexibility — Complex designs involving unusual shapes or thick and thin sections can be produced easily as Malleable castings.

Economy — The strength per dollar offered by Malleable combined with cost-saving machinability and design versatility adds up to lower cost, higher quality parts for you. Any member foundry will be happy to supply further information on Malleable iron.

Malleable Founders Society

Union Commerce Building
Cleveland 14, Ohio

Circle No. 742, Page 167-168

INVESTMENT CASTINGS

are your answer to design and production problems

INVESTMENT CASTINGS GIVE YOU . . .

– DESIGN FLEXIBILITY

– DETAIL REPRODUCTION

– CLOSE DIMENSIONAL TOLERANCES

– A WIDE SELECTION OF ALLOYS

To help you become better acquainted with investment castings, members of the Investment Casting Institute have pooled their collective experience to produce a comprehensive "INVESTMENT CASTING ENGINEERING AND DESIGN MANUAL."

This important industry manual contains recommended tolerances for design criteria, standards for metal specifications, case histories of investment casting applications, and other valuable data. This important industry manual is available to you at its cost price of $2.00. ($2.25 when invoiced)

Obtain your copy now by sending your check and your order to

INVESTMENT CASTING INSTITUTE

27 East Monroe Street **Chicago 3, Illinois**

Circle No. 743, Page 167-168

classified advertising

For Sale, Help Wanted, Personals, Engineering Service, etc., set solid . . 25c per word, 30 words ($7.50) minimum, prepaid.

Positions Wanted . . 10c per word, 30 words ($3.00) minimum, prepaid. Box number, care of **Modern Castings,** counts as 10 additional words.

Display Classified . . Based on per-column width, per inch . . 1-time, $18.00 6-time, $16.50 per insertion; 12-time, $15.00 per insertion; prepaid.

Help Wanted

EXPERIENCED MAN FOR PERMANENT POSITION

wanted as gray iron foundry superintendent. Age range 30-45. Position offers exceptional opportunity for man with ambition. Present operations profitable and prospects good. Starting salary commensurate with ability. Reply air mail to **Box F-137, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

NON-FERROUS FOUNDRYMAN

with good training in metallurgy and sound practical experience who has supervisory qualities to assume direction of sand, permanent mold and centrifugal foundry department of northeastern Ohio corporation. Give full particulars and references in letter to **Box F-136, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

INDUSTRIAL ENGINEER

Experienced in foundry operations as well as general industry. Capable of taking over management of industrial engineering division of ACME member consulting firm. Degree necessary. Age 35-34. Send complete details and include recent photograph. All replies held in confidence. **Box F-135, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

GOOD FOUNDRYMEN

when you need SUPERVISORY or TECHNICAL men why not consult a man with actual foundry experience plus 15 years in finding and placing FOUNDRY PERSONNEL.

Or if you are a FOUNDRYMAN looking for a new position you will want the advantages of this experience and close contact with employers throughout the country.

For action contact:
John Cope
DRAKE PERSONNELL, INC.
29 E. Madison St.
Chicago 2, Illinois
Financial 6-8700

PLANT ENGINEERS

Experienced on layout of all types of foundry equipment, material handling and material flows. Send complete details on work history, education and family status. Include recent photograph. All replies confidential. **Box F-140, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

WANTED — SUPERINTENDENT FOR NON-FERROUS FOUNDRY — EXPERIENCED IN ALL PHASES ON NON-FERROUS FOUNDRY OPERATION. Box F-134, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

PLANT MANAGER—INVESTMENT CASTINGS: New investment casting plant opened by established Midwest foundry. Experienced man required to assume complete responsibility for management of personnel, production, purchasing, tooling design, cost estimating. Must be strong in latest methods and metallurgy, ferrous and non-ferrous. Send complete resumé. **Box F-102, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

Positions Wanted

Experienced foundry salesman desires position with a foundry sales organization. Ten years foundry background, experience in selling refractories, facings, core additives and equipment. Prefer Wisconsin, Illinois area, but will relocate. Age 31, married with four children. **Box F-132, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

FOUNDRY ENGINEER—METALLURGIST—SUPERVISOR desires position where he can grow with progressive foundry. Experience with steel, gray iron (Meehanite) and non-ferrous castings, gating and risering, etc. Age 39. **Box F-131, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

PERMANENT MOLD SUPERVISOR available. Specializing in piston casting—full charge of department including customer contact, new contracts, engineering and mold design, tooling schedule and processing orders. Age 39. Over 16 years experience. Married. **Box F-138, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

SUPERINTENDENT or GENERAL FOREMEN. Have good general knowledge of all foundry practice. Molding, coremaking, cleaning, cupola operations and sand control. Age 45 years. Thirty years experience. **Box F-139, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

ABRASIVE ENGINEER. Seven years experience calling on foundries and shops. Seeks position in the Chicago and northern Illinois area. Have previously called in this area for three years. Prior to this owned my own abrasive distributorship in the Detroit area. **Box F-141, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

MANAGERIAL and/or **SALES.** Over 20 years experience in gray iron, steel, malleable—covers all phases of operations and administration. Above average. College graduate. Technical background. Energetic and ambitious. Good record. Well recommended. Available soon. Salary open. **Box F-130, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

Engineering Services

ED JENKINS
Foundry Consultant
253 Eighth Street
West Palm Beach, Florida
TEmple 2-8685

CONSULTING ENGINEER
THIRTY-FIVE YEARS' EXPERIENCE
Improved methods in electric furnace melting. Analysis control. Low cost, high productivity. Personnel Training. Melt shop designing and modernizing.
EUGENE H. WEAK
HIGHLAND, IND.
2933 HIGHWAY AVENUE
PH: TEMPLE 8-1244

EARL E. WOODLIFF
Foundry Sand Engineer
Consulting . . . Testing
14611 Fenkell (5-Mile Rd.)
Detroit 27, Michigan
Res. Phone VErmont 5-8724

FOUNDRY PRODUCT DEMONSTRATION SERVICE

Nation-wide Service available to manufacturers of foundry equipment and supplies. Unique opportunity to have your present product or a new product personally demonstrated *inside* the prospective customer's Foundry. **Write Box F-133, MODERN CASTINGS Golf and Wolf Roads, Des Plaines, Ill.**

For Sale

RANSAHOFF
TUMBLING MILLS
48" diameter x 84" length
end loading and unloading automatically.
11 cu ft power loader with hoist.
NEW—Government surplus.
Sold at 50% of replacement cost
MILT GROBAN
9656 S. Merrion Avenue
Chicago 17, Illinois
SAginaw 1-3442

WHEELABRATOR 36 x 42, W/SKIP LOADER
AJAX INDUCTION FURNACE 35 K.V.A.
BESLEY OPPOSED DISC GRINDER 23" WHEEL
SHELL MOLDING MACHINE, AUTOMATIC, SIZE 23" x 36"
WELLS MANUFACTURING COMPANY
7800 North Austin Avenue
Skokie, Illinois
INdependence 3-5050
Phone or write **J. T. Moore**

For Sale

ELECTRIC ARC FURNACES FOR SALE Two-2000-lb side-charge furnaces complete with transformers, extra tops and electrodes. Low price for quick sale. **FRED H. WUETIG, 7445 South Chicago Ave., Chicago 19, Illinois HYde Park 8-7470.**

KUX DIE CASTING MACHINES
Model K-5, 25-T. Locking Pressure.
New 1949, Weight 2200#, Extra equipment and brand new.
Model BA-12, 100 T Locking Pressure.
New 1948, Weight 8500#. Very reasonable. Excellent condition.
EVEREADY, BPT., CONN.
Box 618- ED-4-9471-2

Wanted to Buy

BACK VOLUMES — Wanted to buy for cash of foundrymen, TRANSACTIONS American Foundrymen's Society and other scientific technical Journals, **A. S. ASHLEY 27 E. 21, N. Y. 10, N. Y.**

WANTED! BOUND VOLUMES OF TRANSACTIONS OF AFS. Arrangements to sell bound volumes of TRANSACTION of AFS, intact and in good condition, may be made through AFS Headquarters. Those who have no futher use for any volumes of TRANSACTIONS on their bookshelves are requested to communicate with the **Book Department, American Foundrymen's Society, Golf and Wolf Roads, Des Plaines, Illinois.**

NEW SERVICE

MODERN CASTINGS announces a new service available to all members of the American Foundrymen's Society. Any member seeking employment in the metal-castings business may place one classified ad of 40 words in the "Positions Wanted" column FREE OF CHARGE. Inquiries will be kept confidential if requested. Ads may be repeated in following issues at regular classified rates. Send ads to **MODERN CASTINGS, Classified Advertising Dept., Golf and Wolf Rds., Des Plaines, Ill.**

How long?-5 weeks!

■ Remember, when you change your address, five weeks advance notice is necessary to assure that MODERN CASTINGS will be sent to you without interruption. Write to: Circulation Manager, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Illinois.

TEX-VENT
Flexible TEXTILE Core Vent
New venting material for sand cores. Disintegrates completely if core is baked . . . leaves no residue. Allows unrestricted use of cold-setting processes.
DOMESTIC industries, inc.
470 W. Broad St. Columbus, O.

foundry trade news

Continued from page 156

existing model and service parts to the Canadian foundry customers. A contract between the firms has been signed to make the Simpson intensive mixer and spare parts. Officers of the subsidiary firm are B. L. Simpson, president; H. W. Zimnawoda, sales manager, and E. M. O'Connell, treasurer.

Harry W. Dietert Co. . . . Detroit, recently conducted the Dietert-Detroit Sand Strength Machine Contest to determine the oldest sand strength machine in use by a United States foundry. The oldest machine, on which a contest entry was received, is owned by Clio Foundry Inc., Clio, Mich. Manufactured in 1928 it is still used eight times a day. Mr. R. L. Calkins, president of Clio, is winner of a new No. 405 Universal Sand Strength machine. Other reported "old-timers" in daily use are at: Sall Brothers Co., Rockford, Ill.; Blaw-Knox Co., Pittsburgh, Pa.; Galva Foundry Co., Galva, Ill.; Chicago Malleable Castings Co., Chicago; Detroit Stoker Co., Detroit and Battelle Memorial Institute, Columbus, Ohio. Dietert is particularly proud of an entry from Chevrolet-Saginaw Grey Iron Foundry, Saginaw, Mich. Their 1931 strength machine is being used 340 times a day. Consolation awards were sent to the seven runners-up.

General Electric Co. . . . Foundry Dept., Schenectady, N. Y., sent A. E. Blake, manager-engineering, and Dr. Jack Keverian, manager-applied research and development laboratory, on a fifth European foundry tour. They will obtain information and data on latest European techniques in the field of foundry metallurgy with special emphasis on vacuum technology. Countries being visited are France, Switzerland, Italy, West Germany, Belgium and Scotland.

Sheboygan Foundry Co. . . . Sheboygan, Wis., has been formed by five men who purchased the machinery, equipment and real estate of Sheboygan Castings Corp. The new owners are: Ben Locke, president, Gus Holman Co., Sheboygan; Charles Locke, vice-president, same firm; R. J. Goldberg Sr.; R. J. Goldberg, Jr.; and Chester Goldberg who operate foundries at Grafton, Plymouth and Adell, Wis.

OLIVER
BAND SAW
takes 35 inches under guide to saw extra large patterns

This Oliver Band Saw is powerful and sturdy. Gives clearance for sawing large patterns, jigs and fixtures. Has 36" diameter wheels. Cuts true and steady without vibration at all speeds. Motor-on-shaft unit, and latest features.

Write for Bulletin No. 416-DH

OLIVER MACHINERY COMPANY
Grand Rapids 2, Mich.
Circle No. 744, Page 167-168

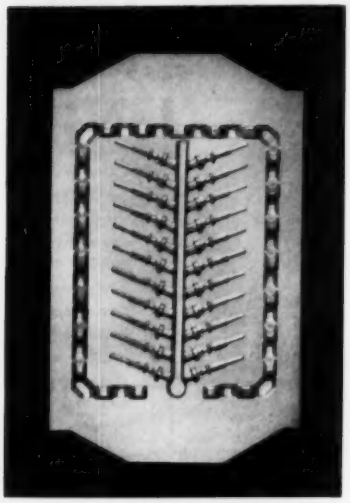
Quality UP
Cost DOWN
through
"Statistical Quality Control for Foundries"

128 pp. 15 tables
6 figures
Chapter titles include:

- Sand Control Applications
- Melting Practice
- Quality Control Applications in the Coreroom
- Applications in Molding Practice
- Pouring Practice
- Installing the Quality Control System & Training Personnel
- Calculations Involved in Quality Control
- Acceptance Sampling

Member Price $4.50
Non-Member Price $6.75
order from:
American Foundrymen's Society
Golf & Wolf Rds.,
Des Plaines, Ill.

NOW the GEFSCORP INTER-LOCK BORDER



ORDER — SCIENTIFIC *GEFSCORP MATCHPLATES

"BEST LOCK YET" SAY FOUNDRIES

— A Serious Improvement Worth a Try —

THE SCIENTIFIC CAST PRODUCTS CORP.

CLEVELAND 1390 E. 40th — CHICAGO 2520 W. Lake

*Mf'd under licence from GEFSCORP, Cal.

Circle No. 746, Page 167-168

New Improved Ceramic Shell Molds Cut Process Time 50% ...Material Cost 40%

You, too, can now enjoy the benefits of the complete Nalcast mold making system like many leading investment casting foundrymen. Less process time...lower material cost...closer tolerances...larger castings...simpler methods, are some. Ask us for the full story. See how easily you can install this system to save time and money. No obligation, of course.

FAST, DEPENDABLE SERVICE

As Eastern distributor of Nalcoag and Nalcast for National Aluminate Corporation of Chicago, Alexander Saunders & Company can serve you quickly and dependably.

Phone or write us for your Nalcast needs or for conventional investment casting requirements. For both, we recommend—

• Saunders Blue Wax • Sherwood Wax Injection Presses • Ecco High Frequency Melting Equipment • and many other proven products

Send for Catalog #56 for complete listing and description.

ALEXANDER SAUNDERS & CO.

95 Bedford Street, New York 14, New York

Circle No. 747, Page 167-168

advertisers and their agencies

The Adams Co. 143
Agency—W. D. Lyon Co.
Allied Chemical Corp.,
Semet-Solvay Division 157
Agency—Benton & Bowles
Allis-Chalmers Mfg. Co. 146
Agency—Bert S. Gittens Adv.
Alloy Casting Institute 151
American Colloid Co. 19
Agency—Robert A. Gallagher
American Die Casting Institute 152
American Foundrymen's Society 165
American Machine and Metals Inc. 142
Agency—L. W. Ramsey Adv.
Apex Smelting Co. .....Back Cover
Agency—Doremus & Co.
Archer-Daniels-Midland Co. 16, 17
Agency—Bayless-Kerr Co.
Beardsley & Piper Division,
Pettibone Mulliken Corp. 9
Agency—Ladd, Southward & Bentley
Carver Foundry Products Co. 3
Agency—Warren & Litzenberger
Cities Service Oil Co. 154
Agency—Ellington & Co.
Cleveland Flux Co. 10
Agency—Brad Wright Smith Adv. Inc.
Foundry Design Co. 13
Agency—Herington Adv. Inc.
Foundry Educational Foundation 159
Foundry Services, Inc. 148
Agency—Kight Adv. Inc.
Gray Iron Founders' Society 158
Agency—Will, Inc.
Hanna Furnace Corp. .....Inside Front Cover
Agency—Campbell-Ewald Co.
Hansberg Shooters, Inc. 147
Agency—Bawden Bros. Inc.
Holzman Metal Co. 142
Agency—Milton Sharp, Adv.
Frank G. Hough Co. 12
Agency—Erwin R. Abramson Adv.
International Nickel Co. 22
Agency—Marschalk & Pratt
Investment Casting Institute 163
Lester B. Knight & Assoc. 137
Agency—Reach, McClinton & Pershall
Lindberg Engineering Co. 14
Agency—Don Colvin & Co.
Magnesium Association 145
Magnet Cove Barium Corp. 150
Agency—Troxell & Assoc.
Malleable Founders' Society 162
Markal Company 144
Agency—Paul J. Steffan Co.
L. H. Marshall Co. 8
Agency—Weber, Geiger & Kalat Inc.
Modern Castings 135
Modern Equipment Co. 4
Agency—Jay Ferch & Assoc.
National Metal Abrasive Co. 149
Agency—G. A. Saas and Co.
National Steel Corp.,
Hanna Furnace Corp. Div. Inside Front Cover
Agency—Campbell-Ewald Co.
Non-Ferrous Founders' Society 155
Agency—Charles E. Yost
North American Refractories Co. 156
Agency—Clifford A. Kroening Inc.
Ohio Ferro-Alloys Corp. 139
Agency—Frease & Shorr Adv.
Oliver Machinery Co. 165
Agency—Webb J. Van Dyke
Pittsburgh Crushed Steel Co. 140
Agency—Coleman Todd & Assoc.
Pettibone Mulliken Corp.,
Beardsley & Piper Division 9
Agency—Ladd, Southward & Bentley
Reichhold Chemicals, Inc. 11
Agency—MacManus, John & Adams
Roura Iron Works, Inc. 20
Agency—Marsteller, Rickard, Gebhardt & Reed
Royer Foundry & Machine Co. 15
Agency—Richardson, Thomas & Bushman
Alexander Saunders & Co. 166
Agency—Steve Devore Co.
Scientific Cast Products Corp. 166
Agency—Marshall & Mendes
Semet-Solvay Division,
Allied Chemical Corp. 157
Agency—Benton & Bowles Inc.
Standard Horse Nail Corp. 144
Agency—George Denhart Adv.
Steel Founders' Society 160
Agency—Bayless-Kerr Co.
Sterling National Industries Inc. 161
Agency—Hoffman, York, Paulson & Gerlach
Syntron Company 18
Agency—Servad, Inc.
Chas. Taylor Sons Co. 141
Agency—Keelor & Stites Co.
Union Carbide Metals Co., Div.
Union Carbide Corp. ..Inside Back Cover
Agency—J. M. Mathes, Inc.
Universal Clay Products Co. 6
Agency—Scheel Adv. Agency
Whiting Corp. 7
Agency—Waldie & Briggs Inc.
Woodward Iron Co. 153
Agency—Sparrow Adv. Agency

This index is published as a convenience to the readers. While every care is taken to make it accurate MODERN CASTINGS assumes no responsibility for errors or omissions.

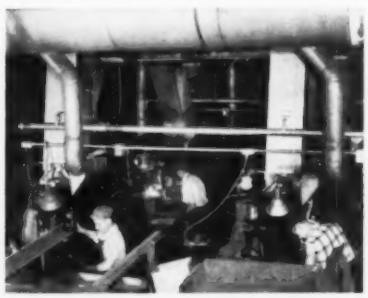
Plant-Made Air Condition System Ups Foundry Morale

■ When a plant is either too cold or too hot, it's no secret that employee morale and production will probably drop in direct proportion to the degree of discomfort.

Crouse-Hinds Co., Syracuse, N. Y., experienced this problem in its foundry. During the average summer, a full week was usually lost in down-time because it was too hot to work. Personnel working at molding stations, pour-off areas and shakeout suffered the most; management decided to do something about it.

They enlisted the aid of the firm's tin shop which came up with duct work for an air replacement system. Now, filtered, fresh air is drawn directly from outside the building and delivered to the molding, pouring and shakeout areas.

Molders may direct and adjust the flow of air to suit their individual



needs; each station has a separate venting system.

Company officials report during the two years since installation of system, only one-half day has been lost because of environmental discomfort.

YES! . . . I want to receive MODERN CASTINGS for one year at $5.00 in U.S., $7.50 elsewhere.

☐ Payment is enclosed ☐ Bill me

Name ..... Position or Title ..... Important

Address ☐ Home .....
☐ Business .....

City .....Zone .....State .....

Company .....

Subscribe! Don't put up with a second-hand, pass-along copy. Use this card to get a fresh, uncut, unclipped copy each month.

Subscribe to MODERN CASTINGS

When you see a "Circle No." under an item or an ad, it means that there is more information available.

Send for FREE INFORMATION

Please type or print March/59

Please have information or bulletins indicated by circled numbers sent to me without obligation.

Name _____ Title _____

Company _____

Address _____

City _____ Zone _____ State _____

521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540
541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560
561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580
581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600
601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620
621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640
641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660
661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680
681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700
701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720
721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740
741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760

Please use card before September 1, 1959

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD
First Class Permit No. 83, Sec. 34.9 P. L. & R. DES PLAINES, ILL.

Reader Service Dept.
MODERN CASTINGS
Golf & Wolf Roads
Des Plaines, Illinois

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD
First Class Permit No. 83, Sec. 34.9 P. L. & R. DES PLAINES, ILL.

MODERN CASTINGS
Golf & Wolf Roads
Des Plaines, Illinois

Subscribe! Don't put up with a second-hand, pass-along copy. Use this card to get a fresh, uncut, unclipped copy each month.

Subscribe to MODERN CASTINGS

When you see a "Circle No." under an item or an ad, it means that there is more information available.

Send for FREE INFORMATION

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD
First Class Permit No. 83, Sec. 34.9 P. L. & R. DES PLAINES, ILL.

Reader Service Dept.
MODERN CASTINGS
Golf & Wolf Roads
Des Plaines, Illinois

Please type or print **March/59**

Please have information or bulletins indicated by circled numbers sent to me without obligation.

Name _____ **Title** _____

Company _____

Address _____

City _____ **Zone** _____ **State** _____

521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540
541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560
561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580
581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600
601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620
621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640
641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660
661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680
681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700
701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720
721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740
741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760

Please use card before September 1, 1959

"I always get good ductility using calcium alloys"

Steel foundries employing aluminum deoxidation obtain improved properties by making a supplementary addition of calcium-silicon or calcium-manganese-silicon to the ladle. These calcium alloys help obtain consistently good ductility in the tensile test. Many foundries also report improved fluidity with the calcium additions. Generally 3 to 5 lbs. of alloy per ton insure effective treatment.

UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation, 30 East 42nd St., New York 17, N. Y.

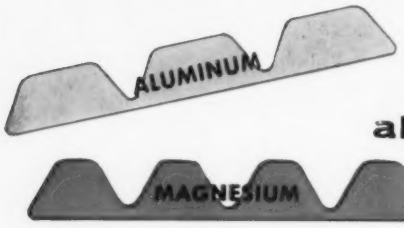
Contact your UNION CARBIDE METALS representative for further information on getting improved ductility with calcium alloys.

UNION CARBIDE METALS

Electromet *Brand Ferroalloys and other Metallurgical Products*

The terms "Electromet" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

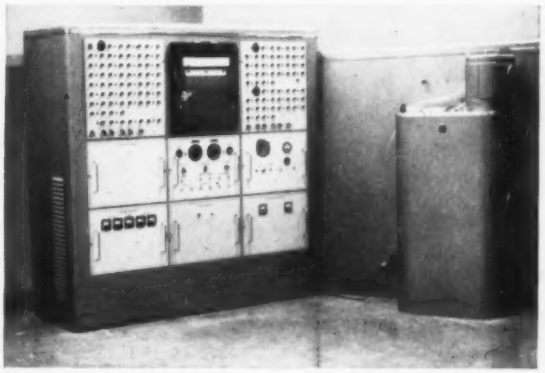
ALLOY INGOT FOR SAND, PERMANENT MOLD AND DIE CASTING



How APEX Production Control produces alloys tailored to your specifications with certified accuracy

Your specification page in the Apex Spec Book controls your ingot production—holding alloy elements to desired content for castability and maximum properties.

Once recorded, your particular specs become the formula for your alloy production in all Apex plants. Under meticulous control, you receive an alloy to meet casting applications requiring special mechanical properties, physical properties, machinability, corrosion resistance or other individual needs. The Spec Book also includes specifications for all standard alloys conforming to governmental and society specifications.



The QUANTOMETER assures you of an alloy conforming to your specifications

Our sales engineers will gladly discuss the Apex production control system as it applies to your casting requirements. Call on us now for composition accuracy and prompt shipment of your alloys.

APEX SMELTING COMPANY

CHICAGO 12 • CLEVELAND 5 • LONG BEACH 10, CAL.
SPRINGFIELD, OREGON (NATIONAL METALLURGICAL CORP.)

Base metal and alloy SPECTROGRAPHIC STANDARDS available • Aluminum • Magnesium • Zinc

Circle No. 749, Page 167-168